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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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And Auxiliary Machinery as supplied to the Admiralty. 2179

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Two Excellent VERTICAL DRILLING MACHINES.
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Specification and Workmanship equal to Main Line Locomotives.
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for Engine Works and Boiler Shops.
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See page 17, Oct. 5. 1134

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TRANSPORTER CO., LTD.,
CONTRACTING ENGINEERS.
DESIGNERS and BUILDERS
of
all Classes of HANDLING MACHINERY.
Atlantic House,
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GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
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Chief Offices: 120, Trongate, Glasgow. Od 8547
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See's Patent Hydro-Pneumatic **Ash Ejector**
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4835

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TUTORS, 254, Oxford Road, Manchester. Estab. 1876. Enrol now for I.C.E. and I.M.E. Postal Courses, 100 per cent. passes last Exams. Reinforced Concrete—a new comprehensive course under expert engineer, £3 3s. Write for particulars. 968

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Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 817
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 73.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM and GAS KNITTLES, } Row's PATENTS.
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SYPHONIA STEAM TRAPS, REDUCING VALVES.
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

IRON & STEEL
Tubes AND Fittings
AND
Steel Plates.

STEWARTS AND LLOYDS, Ltd.
GLASGOW - BIRMINGHAM - LONDON.
See Advertisement, page 91. 1111

Drag Line Excavator.
Has moved 2,000 cube yards in one day. May be seen at Frodsham, near Chester. Reach 77 ft.; lift four to five tons; speed of working, one to three cuts a minute.
HARRY FAIRCLOUGH, Contractor.
WARRINGTON. 1150

Guillotine Shears and Power Presses
FOR SHEET AND PLATE WORKING.
THE REGENT SHEET METAL MACHINE TOOL CO., LTD.,
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Makers of
Evaporating and Distilling Plants.
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Feed Water Heaters.
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Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c., &c. 1536

E. J. Davis, M.I.Mech.E., Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: Maryland 1736 & 1737. Wire: "Rapidising, London."—Great Eastern Road, Stratford, E. 15. 1794

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Hurst, Nelson & Co., Ltd.,
Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH WORK, IRON & BRASS CASTINGS.
PRESSED STEEL WORK OF ALL KINDS.
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HIGH CLASS
Machine Cut Gearing
FOR EVERY PURPOSE. 1440

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Carels Diesel & Steam Engines. 1120
CARELS DIESEL & STEAM ENGINES (LONDON) LTD., Kinnaird House, 1, Pall Mall East, S.W. 1.
Telephone: Regent 3494.

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LAND AND MARINE
YARROW BOILERS. 1553

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GENERAL CONSTRUCTIONAL ENGINEERS. 1216
Boilers, Tanks & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 35, Oct. 5. 2402

Two Exceptionally Good
Second-hand 30 B.HP. CROSSLEY SUCTION GAS ENGINES, Nos. 77744, 75211, Type S.H. 119, with open hearth Producer Plants, latest design, low price before removal.
WASTE HEAT BOILER by Penman, evaporation 3500 lbs. per hour, 125 lbs. w.p. New 1922.
VERTICAL BOILER by Ruston, 13 ft. 6 in. by 6 ft. 3 in., 120 lbs. w.p., 3300 lbs. evaporation.
200 HP. ENCLOSED SELF LUBRICATING HIGH SPEED ENGINE by Allen, 375 r.p.m. 150 lbs. w.p.
WEIR BOILER FEED PUMP, 10,000 gallons per hour, 180 lbs. w.p.
HORIZONTAL STEAM ENGINE by Robey, Jet Condensing, Cylinder 17 in. by 36 in.
HARRY H. GARDAM & CO., LTD., Staines. B 725

Power and Speed of Vessels.
—Practical Course of Instruction by Correspondence.—Address, for particulars and terms, 1403, Offices of ENGINEERING.

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED,
DARLINGTON. 1312

For Your Repairs or any
SPECIAL MACHINERY, try—
THOMAS HUNT & SONS,
Albion Ironworks,
Bridge Road West, Battersea, S.W. 11.
Est. 1854. 1642

WAYGOOD-OTIS LIFTS 1415
54 & 55, FETTER LANE, LONDON, E.C. 4,
62 & 63, LIONEL STREET, BIRMINGHAM,
and Principal Provincial Cities and Abroad.

Petter Oil Engines.
For Paraffin and Crude Oil
Sizes 1½ B.HP. and upwards
Petters Limited, Yeovil.
Sizes 25 to 500 B.HP.
Vickers-Petters, Ltd., Ipswich
See advertisement alternate weeks. 9315

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 1676
See half-page Advertisement, page 36, Sept. 28.

The Manchester Steam Users' Association.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, Mount Street, Manchester.
Chief Engineer: C. E. Stromeyer, M.I.C.E.
Founded 1854 by Sir William Fairbairn.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

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Inst.C.E., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and All Engineering Examinations personally conducted by Mr. Trevor W. Phillips, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., etc., Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, Trafford Chambers, 58, South John Street, Liverpool. 1295

TENDERS.

Tenders are Required in Cairo

not later than Noon on the 31st December, 1923, by the Ministry of Public Works, Mechanical Department, for the supply of a STEAMER for the Upper White Nile Division.—Specifications can be obtained from the INSPECTING ENGINEER Egyptian and Sudan Governments, Queen Anne's Chambers, Westminster, S.W.1. on payment of 5s. 1d. B 836

The Director-General,

India Store Department, Branch No. 16, Belvedere Road, Lambeth, S.E.1, REQUIRES :—

1. OIL TANK WAGONS (railway). Required for shipment by middle of February, 1924.
2. MILD STEEL BARS and JOISTS.
3. MILD STEEL PLATES and SHEETS. Black and Galvanized, Plain and Corrugated.
4. IRON BARS for Horsfall Nut-making Machines.

Tenders due on the 30th October, 1923.
Tender forms obtainable from above. B 843

BENGAL-NAGPUR RAILWAY COMPANY, LIMITED.

The Directors are prepared to receive

Tenders for :—

8000 yards of WATERPROOF CANVAS.
Specification and Form of Tender can be obtained at the Company's Offices, 13J, Gresham House, Old Broad Street, London, E.C. 2, on or after 5th October, 1923.
A fee of 10s. will be charged for the Specification, which is NOT returnable.
Tenders must be submitted not later than NOON, on Tuesday, 16th October, 1923.
The Directors do not bind themselves to accept the lowest or any Tender.
By Order of the Board,
R. C. VOLKERS,
Secretary. B 817

TENDERS INVITED.

COUNTY OF LONDON ELECTRIC SUPPLY CO., LTD.

BARKING POWER STATION.

The County of London Electric Supply Co., Ltd., are prepared to receive

Tenders for the Supply of

CONDENSER TUBES for their Barking Power Station.
Specifications may be obtained by manufacturers from the offices of the Company on application to the undersigned, on or after the 10th October, 1923.
Sealed Tenders, marked "Tender for Condenser Tubes for Barking Power Station," are to be addressed to the Chairman and Managing Director, and lodged at the registered offices of the Company by Noon on 30th October, 1923.
The Company do not bind themselves to accept the lowest or any Tender.
F. C. McQUOWN,
Manager and Secretary,
County of London Electric Supply Co., Ltd.,
Moorgate Court, Moorgate Place, London, E.C. 2.
B 833

STATE ELECTRICITY COMMISSION OF VICTORIA.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY, etc., of the following for the Morwell Power Scheme.
Copies of Tender Form and Specification will be available upon application to :—
AGENT-GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C.2.
Specification No. 24/1—
ALUMINIUM STEEL CORED CABLE AND ACCESSORIES.
Charge :—10s. for the first two copies of Tender Form, Conditions of Contract and Specification complete. This charge will be returned on receipt of a *bona fide* Tender. A third copy and any further copies will be supplied for the sum of 5s. each. This charge is not returnable.
Preliminary Deposit :—A Preliminary Deposit of £100 is to be lodged with the Tender.
The Specification may be inspected at the above-mentioned office.
The Commission does not bind itself to accept the lowest or any Tender.
Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned in Melbourne, not later than 5 p.m., 3rd January, 1924.
R. LIDDELOW,
Secretary,
State Electricity Commission of Victoria,
Melbourne, Victoria,
Australia. B 846

BOMBAY, BARODA & CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to Noon on Friday, 2nd November,

Tenders for the Supply of :—

1. STEEL MATERIAL.
2. WHEELS and AXLES for WAGONS.

Tenders must be made on Forms, copies of which, with Specification, can be obtained at these Offices on payment of 20s. each (which will not be returned).
The Directors do not bind themselves to accept the lowest or any Tender.
S. G. S. YOUNG,
Secretary.
Offices : 91, Petty France,
Westminster, S.W.1.
10th October, 1923. B 882

THE GREAT INDIAN PENINSULA RAILWAY COMPANY, 48, Copthall Avenue, London, E.C. 2, invite

Tenders for :—

		Fee for Specification.
1.	Steelwork for Bridges	10/-
2.	Solid Drawn Steel Boiler Tubes	7/6
3.	Steel Tyres for Locomotive Engines and Tenders ...	7/6
4.	Points and Crossings, etc. ...	10/-
5.	Rolled Steel Check-Rail Bars and Fastenings	5/-
6.	Expanded Metal	5/-
7.	Wood Handles	2/6
8.	Leather Belting, etc.	7/6
9.	Chintz, Turbans, etc.	5/-

Tenders are due by Eleven a.m., on 23rd October, 1923.
Tender forms obtainable at above address.
Fees not returnable. B 874

STATE ELECTRICITY COMMISSION OF VICTORIA.

Tenders are Hereby

Invited for the SUPPLY, DELIVERY etc., of the following for the Morwell Power Scheme,
Copies of Tender Form and Specification will be available upon application to :—
THE AGENT-GENERAL FOR VICTORIA,
Melbourne Place, Strand,
London, W.C.2.
Specification No. 23/145—4 only 1,000 K.V.A. SINGLE PHASE TRANSFORMERS & SPARES.
Charge :—10s. for the first two copies of Tender Form, Conditions of Contract and Specification complete. This charge will be returned on receipt of a *bona fide* Tender. A third copy and any further copies will be supplied for the sum of 5s. each. This charge is not returnable.
Preliminary Deposit :—A Preliminary Deposit of £25 is to be lodged with Tender.
The Specification may be inspected at the above-mentioned office.
The Commission does not bind itself to accept the lowest or any Tender.
Tenders on prescribed form, properly endorsed and addressed, must be delivered to the undersigned, in Melbourne, not later than Noon, 15th December, 1923.
R. LIDDELOW,
Secretary,
State Electricity Commission of Victoria,
Melbourne, Victoria,
Australia. B 845

ADMINISTRATIVE COUNTY OF LONDON.

NORTH WOOLWICH DRAINAGE—NEW 14 IN. DIAMETER RISING MAIN.

The London County Council invites

Tenders for :—

PROVIDING, LAYING, and FIXING, about 1¼ miles of DOUBLE LINE of CAST IRON SOCKET and SPIGOT PIPES, together with Air Valves, Connection to Existing Wash-out Pipes, etc., and the REMOVAL of the DOUBLE LINE of OLD 14 in. MAINS, in the Boroughs of East Ham and Woolwich.
Persons desiring to submit Tenders may obtain the form of Tender, etc., on application to the Engineer, at the Old County Hall, Spring Gardens, S.W.1., upon payment of the sum of £5. This amount will be returnable only if the tenderer shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the contract documents may be inspected before the payment of the fee.
No Tender received by the Clerk of the Council at the County Hall, Westminster Bridge, S.E. 1, after Twelve NOON on Tuesday, 30th October, 1923, will be considered.
The Council does not bind itself to accept the lowest or any Tender.
JAMES BIRD,
Clerk of the London County Council.
B 858

APPOINTMENTS OPEN.

THE BRITISH CAST IRON RESEARCH ASSOCIATION.

APPOINTMENT OF DIRECTOR OF RESEARCH.

The Council invite

Applications for the Post of

DIRECTOR OF RESEARCH of the Association, at a commencing salary, not exceeding £900 per annum, according to Scientific attainments.
The duties of the Director will be to attend to the Scientific and Metallurgical Engineering Research work of the Association.
Forms of application, can be obtained from the undersigned, which are to be returned on or before October 20th, 1923.
THOS. VICKERS,
Secretary.
Central House,
75, New Street,
Birmingham.
September 21st, 1923. B 813

NATAL TECHNICAL COLLEGE, DURBAN, S. AFRICA.

REQUIRES ASSISTANT LECTURER IN CHEMISTRY AND PHARMACY.

The Council of the Natal Technical College

Require the Services of an

ASSISTANT LECTURER in Chemistry from the 1st of February, 1924. University degree and Pharmacy major qualification desirable. Salary £400-20-£584. Passage paid to Natal and half salary on voyage. Three years' agreement.—Form or application and further particulars obtainable from Mr. J. H. NARBETH, C.B., C.B.E., M.V.O., 65, Sedlescombe Road South, St. Leonards-on-Sea. B 884

Works Manager Wanted for

large bridge and steel constructional works in North-East of England. Man of good education preferred, age about 35. Applications from men with suitable experience only will be considered.—Address, giving full particulars and salary required, to B 878, Offices of Engineering.

Wanted, General Manager,

competent, to take complete charge, both from Technical and Commercial sides of Engineering Works in India and an Agency Department. Must be thoroughly up to date as regards Foundry and Machine Shop practice, while a knowledge of drop stamping, textile machinery and some experience of native labour would be a recommendation. Good salary to good man.—Write, Z.L., 777, c/o Deacon's, Leadenhall Street, London. B 852

Manager Required by an

Established Firm of Iron, Steel and Builders' Merchants. Must be a sound Commercial Man and Organiser, and have experience in Colliery, Engineers', Ship Repairs and Builders' requisites, with good knowledge of various markets.—Address, stating age, qualifications, experience and remuneration, B 867, Offices of Engineering.

A London Engineering Firm

manufacturing office machinery of special character, REQUIRES a FEW MEN to train for Maintenance work in the field. Applicants must have had training and experience as mechanics and charge-hands on intricate work, although men with special mechanical aptitude will be considered. Men previously engaged on repetition work or others should not apply. Wages paid will be above district rate while training and 10% or more above when transferred from Works. State age, where educated.—Address, B 879, Offices of Engineering.

Wanted, Several Good

MACHINE TOOL MAKERS. Men accustomed to setting up and running Automatic Screw Machines preferred. Must be accustomed to working to fine limits. Full particulars must be given.—Address, TOOL, Wm. Porteous & Co., Advertising Agents, Glasgow. B 771

Wanted, Erector for Mechanical

Chain Grate Stokers, previous experience essential. Apply stating age, experience and salary required. Preference given to man with knowledge of combustion conditions.—Address, B 826, Offices of Engineering.

Retired Artificers, R.N.—

Company operating in East Africa, REQUIRES THREE ENGINEERS, one must be a Specialist on Water Tube Boiler repairs, one General Engineer with experience on erection of Machinery, and one General Engineer with good knowledge of Oil Engines, about 40 HP. Salary about £360 per annum, with one servant allowance and free quarters. Passage out and home, Three years' agreement. —Write, sending copies only of testimonials which will NOT be returned, to W.W., c/o J. W. Vickers and Co., Ltd., 5, Nicholas Lane, E.C.4. B 830

Temporary Executive

ENGINEER (for Water Supply) REQUIRED by the GOVERNMENT OF UGANDA for the PUBLIC WORKS DEPARTMENT, for a tour of 20 to 30 months' service. Salary £800 a year inclusive. Free quarters and passages, and liberal leave in England on full salary. Candidates, age 32 to 45, must have had considerable experience in the preparation of water supply schemes and in their execution. Should preferably have served as Chief Assistant to the Waterworks Engineer of a large Borough, and be A.M.I.C.E, or A.M.Inst.M. & Cy. E. Apply at once by letter, giving brief details of qualifications and experience, and stating whether married or single, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W.1, quoting M/12227. B 835

THE COMMISSIONERS FOR THE PORT OF CALCUTTA.

Applications are Invited for

ONE MECHANICAL ENGINEER and for THREE ASSISTANT EXECUTIVE ENGINEERS with the following qualifications :—
MECHANICAL ENGINEER.
Candidates must have had not less than 12 years' experience (preferably with contracting engineers) after completion of training. Preference will be given to men with experience and knowledge of dock machinery and equipment. Age 35-40. Salary Rupees 1,200 per month, rising by Rupees 75 to Rupees 1,350 per month. Three years' agreement.
ASSISTANT EXECUTIVE ENGINEERS.
Civil Engineers who have had technical education in Engineering, are physically fit and energetic, and who have had some experience in dock construction. Preference will be given to men who have passed the examination for Associate Membership of the Institution of Civil Engineers or hold an exempting degree. They should be unmarried. Age about 27 years. Salary Rupees 700 per month, rising by Rupees 50 per month to Rupees 800 per month. Three years' agreement.
Applications, with copies of testimonials, to be sent to the undersigned not later than 19th October, 1923.
J. ANGUS, M.Inst.C.E.,
Consulting Engineer & London Agent,
10, Princes Street,
Westminster, S.W.1. B 849

Required for East Africa, an

ENGINEER with experience of Cable Ploughing. Three years' agreement, free quarters and one servant allowance. Free passage out and home.—Write, sending copies only of testimonials which will NOT be returned, stating salary required, to D.M., c/o J. W. Vickers & Co., Ltd., 5, Nicholas Lane, E.C.4. B 832

Two Engineers Required for

East Africa; one must possess good knowledge of Oil Engines, about 40 H.P., and the other with experience on erection of Machinery—Ginnery experience preferred. Salary about £360 per annum with one servant allowance and free quarters. Passage out and home. Three years' agreement.—Write, sending copies only of testimonials which will NOT be returned, to H.D., c/o J. W. Vickers & Co., Ltd., 5, Nicholas Lane, E.C.4. B 831

The Royal Air Force

REQUIRES SKILLED FITTERS. General (for training as Aero Engine Fitters), Fitters Driver Petrol, Electrical Fitters and Power Station tradesmen. Age limits :—Ex-Service men 18 to 30; Non-Ex-Service 18 to 26; highly skilled Fitters up to 35. Ex-N.C.O's up to 36 years (with rank according to trade ability). Pay from 21s. to 66s. 6d. per week, on enlistment, and all found. Allowance for wife and children to men 26 and over.—Write, stating age, or call :—INSPECTOR OF RECRUITING, R.A.F., 4, Henrietta Street, Covent Garden, W.C. 2. B 759

Assistant Engineer

REQUIRED for Railway Construction, NIGERIA, for two tours of 12 to 18 months' service with possible extension. Salary, £480 for first three years of service and then £510 rising to £720 a year by annual increments of £30, and thence to £920 by annual increments of £40. Outfit allowance of £60 on first appointment. Free quarters or an allowance in lieu. Free passages and liberal leave in England on full salary. Candidates, aged 25 to 40, must have had experience of Railway Construction, of timber pile driving and under water work in connection with slipways, also concrete work generally and more especially in bridges, piers, and arched culverts.—Apply at once in writing, stating age and brief details of experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W.1, quoting M/Nigeria 12220. B 869

MADRAS AND SOUTHERN MAHRATTA RAILWAY COMPANY, LIMITED.

An Assistant Electrical

ENGINEER is REQUIRED in January next on the Company's staff in India. Candidates must be of non-Asiatic descent, unmarried, not more than 30 years of age, and the qualifications asked for are as follows :—
A Public School education, a thorough training, both technical and practical, in electrical engineering, and possession of some approved engineering diploma.
The Company maintains a considerable portion of its own telegraph lines and manufactures and repairs its own telegraph and block instruments, telephones, etc., and a knowledge of the manufacture of such instruments and of line construction and maintenance would be a recommendation. This qualification might possibly be obtained by a candidate at his own expense before sailing.
Starting Salary.—According to age and qualifications with a maximum of Rs. 825 per mensem, rising according to the rules in force.
Terms.—Subject to a strict Medical Examination by the Company's Consulting Physician, a three years' agreement in the first instance, a first class free passage to India, and home again on satisfactory termination of agreement, which is extensible by mutual consent. Employees are required to subscribe one month's pay yearly to the Company's Provident Fund, and to those of over five years' service, a bonus equal to their contribution is credited, both bonus and contributions accumulating at compound interest until retirement.
Applications should be made by letter only, giving details in chronological order, with dates of general and technical education and practical experience. Special forms of application, which must be returned by 29th October, 1923, will be sent to applicants who appear to have the necessary qualifications.
25, Buckingham Palace Road, S.W.1. B 850

MADRAS AND SOUTHERN MAHRATTA RAILWAY COMPANY, LIMITED.

An Assistant Engineer

is REQUIRED in the Way and Works Department.
Candidates must be of non-Asiatic descent, unmarried, not more than 27 years of age, and the qualifications required are as follows :—
A Public School education, technical education at a recognised Engineering College, possession of a certificate of having passed the examination for the Associate Membership of the Institution of Civil Engineers or of an exempting degree.
Preference will be given to candidates who have had one or two years' experience as Assistant Engineer with a Railway Company or a Contractor on Public Works.
Starting Salary.—According to age and qualifications with a maximum of Rs. 675 per mensem, rising according to the rules in force.
Terms.—Subject to a strict Medical Examination by the Company's Consulting Physician, a three years' agreement in the first instance, a first class free passage to India, and home again on satisfactory termination of agreement, which is extensible by mutual consent. Employees are required to subscribe one month's pay yearly to the Company's Provident Fund, and to those of over five years' service, a bonus equal to their contribution is credited, both bonus and contributions accumulating at compound interest until retirement.
Applications should be made by letter only, giving details in chronological order, with dates of general and technical education, and practical experience. Special forms of application, which must be returned by 29th October, 1923, will be sent to applicants who appear to have the necessary qualifications.
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THE EFFECT OF SCRATCHES AND OF VARIOUS WORKSHOP FINISHES UPON THE FATIGUE STRENGTH OF STEEL.

By W. NORMAN THOMAS, M.A., D.Phil., M.Sc., Assoc.M.Inst.C.E.

THIS research was carried out at the Engineering Laboratory, Oxford, for the Engineering Research Co-ordinating Board of the Department of Scientific and Industrial Research on the recommendation of the Aeronautical Research Committee. The object of the research was to determine to what extent the strength of mild steel, when subjected to fatigue tests, is reduced by small surface scratches, such as are left by the different machining and finishing processes used in engineering shops. For this purpose, the exact shapes of the scratches used in the tests had to be determined, and compared with the shapes of the scratches left by the various finishing processes.

Fig. 1. SECTIONAL ELEVATION.

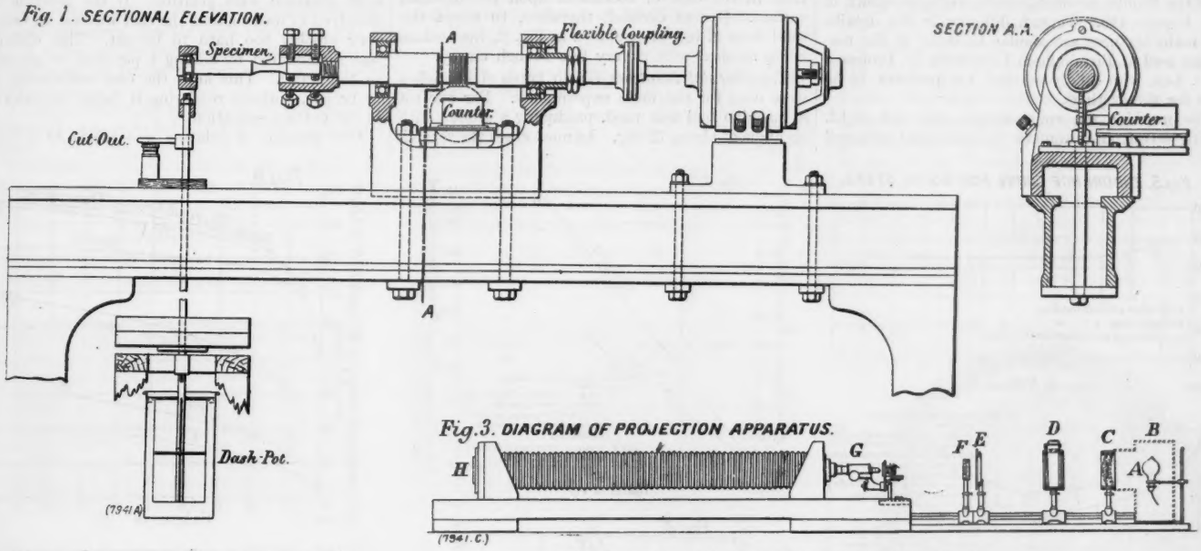
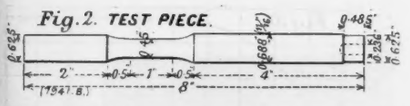


Fig. 2. TEST PIECE.



The results show that, provided the variation in depth is small, the increase of stress depends approximately on the ratio $\sqrt{\frac{d}{\rho}}$, where d is the depth of the scratch and ρ the radius of curvature of its extremity (as was expected on theoretical grounds). The actual reduction of strength, for the small scratches commonly met with, is, however, much less than is indicated by the mathematical theory.

The modern practice in automobile and other branches of engineering, of finishing with a polished surface crank shafts and other parts of machines subjected to alternating stresses, is in itself an indication of the widely held view that surface finish has an appreciable effect upon the endurance of the metal. Very few data, however, seem to be available to indicate the quantitative effect of the various finishes upon the fatigue strength. In none of the previous experimental work bearing upon the subject—so far as the writer is aware—has the shape of the grooves been determined, so that up to the present no satisfactory deductions could be made from the few results that have been obtained.

It is hoped therefore that the results of the present experiments may remove some of the doubt and uncertainty which existed, and provide helpful data for the more complete solution of the very complex problems involved in the phenomena of stress concentrations and fatigue failures.

Theoretical Results.—(1) Dr. Suyehiro* was probably one of the earliest to deal theoretically with the problem of stress concentration. He showed that in the case of a flat plate of unlimited width pierced with a circular hole—provided the elastic limit of the material is not exceeded—the maximum stress in the plate occurs on the transverse diameter of the hole, and its value is three times the mean intensity.

Professor C. E. Inglis* dealt with the subject in more detail. He investigated the problem of the distribution of the stresses in a flat plate pierced either by an elliptical hole, or by any other shaped hole having extremities of an elliptical form.

He extended his theorem to include the case of a flat plate notched at one edge, and showed that the stress R, at the bottom of the notch, is approximately

$$R_1\left(1 + 2\sqrt{\frac{d}{\rho}}\right)$$

where d is the depth of the notch, ρ the radius of curvature at the extremity, and R_1 the mean stress in the plate.

These mathematical investigations assume a steady tension in the plate of such a magnitude that the elastic limit of the material is nowhere exceeded.

The experiments conducted by Dr. Coker,† with his ingenious optical apparatus, have confirmed the above mathematical results obtained by Professor Inglis, and have in addition provided solutions for many other problems concerning concentration of stress.

(3) Dr. A. A. Griffith,* with the aid of his ingenious soap-film apparatus, extended the investigation a further stage. Dealing with a shaft subjected to a twisting moment, his deductions showed that—as long as the material remains elastic—the torsional stresses at the bottom of a V-shaped groove on the shaft are greater than those at the surface of a similar unscratched shaft, according to the values given in Table I, subjoined. The values are independent of the direction of the groove upon the shaft.

He† then showed mathematically that, in the case of a shaft subjected to a bending moment, the ratio of the increased tensile stress to the original maximum tensile stress can be obtained by multiplying the values given in the above table by the

Fig. 3. DIAGRAM OF PROJECTION APPARATUS.

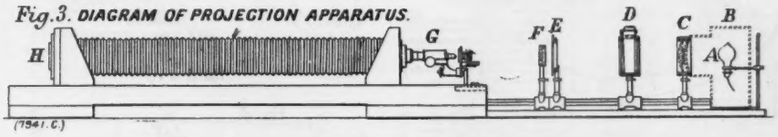


Fig. 4. PROFILES OF EXPERIMENTAL SCRATCHES MAGNIFICATION 180 DIAMETERS EXCEPT WHERE STATED OTHERWISE.

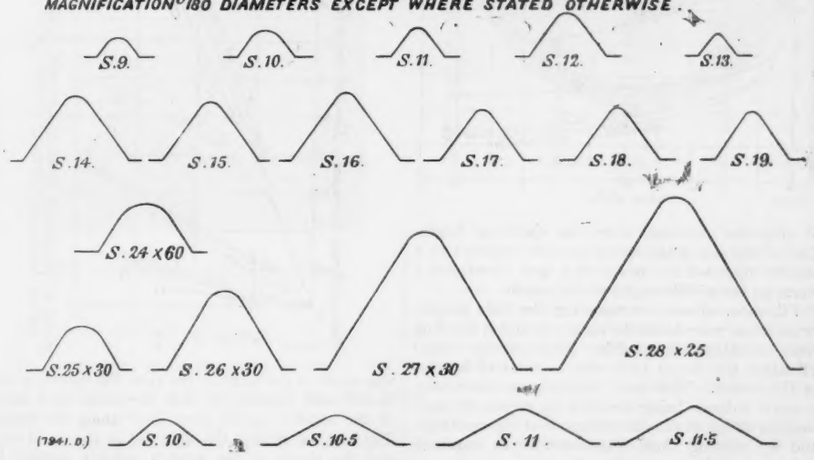


TABLE I.—*Torsional Stresses in Isolated Scratches.*

Angle of V.	Ratio of Maximum Stress at Bottom of Groove to the Surface Stress in an Unscratched Shaft. Values of d/ρ.				
	½	1	3	5	9
deg.					
0	1·85	2·01	2·66	3·23	4·54
60	1·84	2·00	2·54	3·06	3·99
90	1·81	1·95	2·40	2·64	3·12
120	1·66	1·75	1·95	2·06	2·13

* See ENGINEERING, September 1, 1911, page 280.

* "Stresses in a Plate due to the Presence of Cracks and Sharp Corners," C. E. Inglis. Trans. Inst.N.A., Part I, 1913, page 219.

† "The Distribution of Stress due to a Rivet in a Plate." E. G. Coker and W. A. Scoble. Trans. Inst. N.A., Part I, 1913, page 207, and other papers.

* "The Effect of Surface Scratches on the Strength of Shafts and other Members." A. A. Griffith, Advisory Committee for Aeronautics, Report T 1,275, December, 1918. B. 2c. Strength and Design—general 35.

† "Report on the Materials of Construction used in Aircraft and Aircraft Engines." Professor C. F. Jenkin.

ratio $\left(1 + 2\sqrt{\frac{d}{\rho}}\right) / \left(1 + \sqrt{\frac{d}{\rho}}\right)$, provided that the groove is perpendicular to the direction of the stress—*i.e.*, is round the shaft. The ratio is less for grooves in other directions.

As in the case of Professor Inglis's investigations it is assumed that a steady load is applied, and that the material remains perfectly elastic.

The data for curves C and D—which have been plotted in Figs. 6, 8 and 9, for the purposes of comparison with the present writer's results—have been obtained by interpolation from these figures.

Description of Apparatus.—The testing machine is of the Wöhler revolving cantilever type shown in Fig. 1, page 449. Though differing in the details, the main features are similar to those of the machines used at Birmingham University by Professor F. C. Lea, who kindly allowed his patterns to be used for the castings.

The machine ran continuously, day and night, during a test, an automatic cut-out being arranged to stop the machine when the specimen broke. The revolutions of the test-piece were recorded on a counter operated by means of a spur wheel and a worm on the middle length of the spindle.

Fig.5. ENDURANCE CURVE FOR 0·33 C. STEEL.

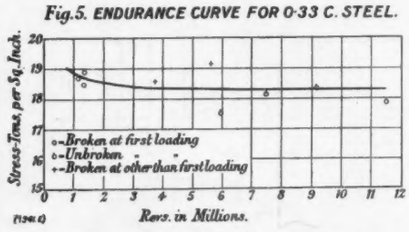
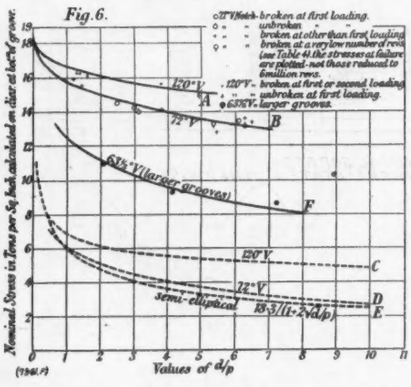


Fig.6.



Vibration.—Before commencing the tests proper, precautions were taken to ensure as much freedom from vibration as possible. Most of the initial vibration was found to be due to want of balance in the motor. This was corrected experimentally, a static balance being obtained by means of small weights added at the circumference of the armature, and by moving these longitudinally as required, a dynamic balance was also obtained.

The tests were run at a speed of about 2,000 r.p.m. to 2,200 r.p.m., as it was found that the machine ran particularly smoothly at that speed.

Test-Pieces.—The material used for the tests was the Aeronautical Research Committee standard 0·33 carbon steel of the following composition :—

	Per Cent.
Carbon	0·33
Silicon	0·22
Manganese	0·59
Sulphur	0·051
Phosphorus	0·049

The bars supplied were 1⅛ in. diameter, and were normalised by being heated to about 850 deg. C. for 15 minutes, and then allowed to cool in the air.

Some preliminary tests were made with hollow test-pieces, as it was realised that in many respects the hollow form would be preferable to the solid form. The chief objection was the difficulty of ensuring that the inner surface should be free from tool scratches.

One of these hollow specimens, with a shallow scratch on the exterior, did not break at the scratch when tested, and it was suspected that the effect of the scratch was masked by the roughness of the interior surface. The broken specimen was therefore cut through lengthways so that the surface could be inspected. To the eye it appeared very rough, but the gelatine casts showed that the grooves were more shallow than they seemed.

From the manner in which the gelatine adhered to the surface, and from the roughness of all the casts taken, it would appear that the material had been subjected to a certain amount of tearing action, and that the "flow"* of the surface layers was less than in the case of toolmarks upon the external surface. It was decided, therefore, to adopt the solid form of test-piece shown in Fig. 2, the surface being finished with a very fine French emery.

Experimental Scratches.—Two types of scratches were used for the main experiments. For one set a machine tool was used, producing a groove with an angle of about 72 deg. In most cases the scratch was made in the lathe at the time the specimen was turned and finished, so that the shape and depth of the scratch varied very little along its length. The tool was held in the slide rest in the usual way, and the depth of the scratch roughly gauged by means of the micrometer dial on the cross-feed screw. The same tool was used for all the specimens S.9 to S.19, the angle being unaltered. The point was touched up occasionally upon an oil stone.

Fig.7.

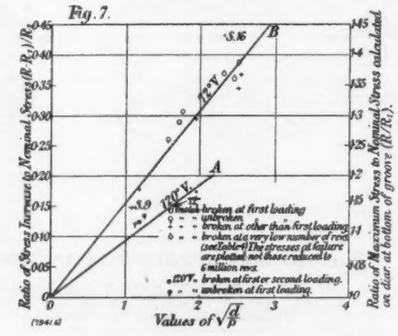
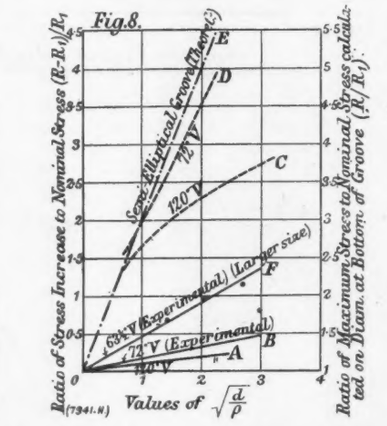

Ratio of Stress Increase to Nominal Stress (R'-R'₁)/R'₁
Ratio of Maximum Stress to Nominal Stress calculated on diar. at bottom of groove (R'/R'₁).
Values of √d/ρ
S.16
S.9
120° V
72° V
A
B
o-Notch broken at first loading
o - - unbroken
+ - - broken at other than first loading
♀ - - broken at a very low number of revs
♂ - - broken at first or second loading.
♀ - - unbroken at first loading.

Fig.8.



For the other set of scratches (S.20 to S.23) a diamond was mounted in a brass holder, and this, used in a similar manner to the machine tool, produced shallow grooves having an average angle of about 120 deg.

The exact shapes of the scratches were determined as described below.

Determination of the Size and Shape of the Scratches.—Preliminary experiments were carried out to see whether the size and shape of the scratches could be determined by direct projection on to a screen, following the method employed at the National Physical Laboratory* for the projection of screw threads. Owing to the large magnification aimed at, the method did not prove to be sufficiently satisfactory. The boundaries of the image on the screen were rendered indistinct by colour fringes, and they could not be made sufficiently sharp for the radius at the end of the groove to be determined with any degree of accuracy. The method was therefore not used except in the case of specimens S.25, S.26, S.27 and S.28, when the magnification was only 60 or 50. A solution (suggested by Mr. Mallock) was sought by preparing casts of the grooves, slicing these with a microtome, and magnifying them by means of the projection apparatus shown in Fig. 3.

Various materials were tried, but the best results were obtained with gelatine. If the gelatine was dissolved in water alone, the cast was apt to become very quickly too hard to be cut. This difficulty was surmounted by adding 4 per cent. of glycerine to the water. This kept the cast sufficiently soft to be cut, without rendering it liable to distortion in the cutting operation.

One gramme of gelatine was added to 5 c.c. of the water and glycerine mixture ; this was dissolved by gently heating in an evaporating dish over a Bunsen flame. Care had to be taken not to allow the mixture to boil, otherwise the liquid became permeated with large numbers of small bubbles which were liable to spoil the casts. A small quantity of a red stain such as Eosin was also added to facilitate the taking of the photographs.

Fig.9.

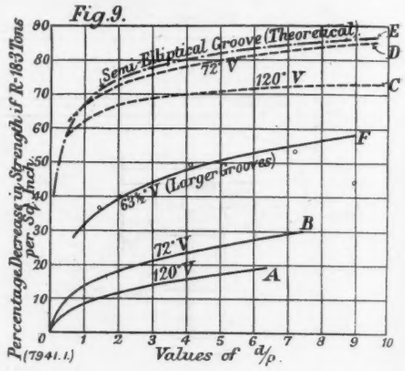
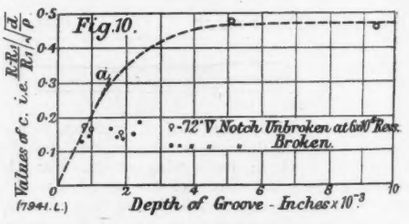


Fig.10.



The casts were made by applying a little of the hot liquid to the surface of the specimen, the latter having previously been slightly warmed. After 24 hours or so, the cast could be peeled off the test-piece, mounted with seccotine on a cork and cut with the microtome. The side of the gelatine with the cast of the scratch was not brought into contact with the cork.

Several checks were applied to verify the truth of the casts—to ensure that there was neither shrinkage nor expansion, nor any appreciable distortion due to the cutting operation.

The gelatine slices were placed upon a glass slide, protected with a cover slip, and placed in the projection apparatus, where a magnification of 360 diameters was obtained upon the screen.

The photographs reproduced in Figs. 11 and 12, show gelatine casts of scratches made respectively with the machine tool and with the diamond point.

Similarly, the photograph reproduced in Fig. 13 shows the shape of the groove upon specimen S.25, obtained by direct projection, the magnification being 50 diameters ; while the photograph reproduced in Fig. 14, shows a gelatine cast of the same groove magnified 100 diameters.

The values of $\frac{d}{\rho}$ obtained from the two photographs agree very closely.

* *Vide* "Aggregation and Flow of Solids," Beilby.

† N.P.L. Report, 1919, pages 75 to 78, 80, 81. Journal I.Mech.E., November, 1920, page 1,119.

In Fig. 14, the darker portion of the print represents the gelatine cast, and the striations show that the section was cut in a direction parallel to the surface of the shaft. The lighter portion of the print represents the steel, so that here, as in the other photographs, the scratch is shown projecting upwards into the metal.

In addition to the photographs that were taken of each scratch, a large number of tracings were made. For this purpose, the ground glass screen was removed and a clear glass screen inserted in its stead. By placing some thin tracing paper on the clear glass, a very distinct image could be seen and traced.

The radius of curvature at the bottom of the groove was also measured directly upon the screen, with the aid of a slip of tracing paper on which had been drawn a set of circles to correspond with various radii.

A large number of sections of each scratch was examined—the casts being taken all round the test-piece.

The forms of the scratches on the different test-pieces are shown to a large scale in Fig. 4, the magnifications being as there stated.

RESULTS OF EXPERIMENTS.

Fatigue Strength of the Unscratched Material.—A number of ordinary fatigue tests were conducted upon unscratched test-pieces, in order to determine the endurance curve for the normal material. The results of the tests are plotted in Fig. 5. The limiting fatigue stress for 6,000,000 alternations has been taken as 18·3 tons per square inch.

Tests on Scratched Specimens.—In the tests on these specimens, owing to the lack of information as to the actual effect of a scratch, the test-piece was loaded with a comparatively small load and subjected to about 6,000,000 complete reversals—*i.e.*, the spindle made that number of revolutions. Then, if unbroken, the load was increased and the specimen subjected to a further 6,000,000 alternations, the process usually being repeated until fracture occurred. A certain number of specimens failed at the first loading, while others which were not broken after about 6,000,000 reversals were not further proceeded with.

For each scratch the values of the depth d, the radius of curvature ρ, and the approximate angle of the V were measured, and the values of $\frac{d}{\rho}$ and $\sqrt{\frac{d}{\rho}}$ calculated.

The nominal maximum stress R_2 was calculated on the diameter at the bottom of the groove, and the stress R_1 required to fracture the specimen at 6,000,000 reversals was then estimated from the endurance curve in Fig. 5.

Theory indicates, as already mentioned, that in a specimen scratched with a groove of semi-elliptical shape, the maximum stress is greater than that in an unscratched specimen in the ratio of $\left(1 + 2\sqrt{\frac{d}{\rho}}\right) : 1$. In order to analyse the experimental results obtained in this research, and for the lack of more definite data concerning grooves of other shapes then semi-elliptical, it is assumed, as a basis, that the law for a V-shaped groove is of the same form. It is also assumed that when failure occurs, the actual maximum stress in the material is the same as the fatigue stress in the unscratched material, *i.e.*, that in these experiments, the real stress R at the bottom of the groove is 18·3 tons per square inch for failure at 6,000,000 reversals.

Assuming then $R = R_1\left(1 + 2\sqrt{\frac{d}{\rho}}\right)$, the ratio of the increase of stress to the nominal maximum stress is

$$\frac{R - R_1}{R_1} = 2\sqrt{\frac{d}{\rho}}$$

where R_1 is the nominal maximum stress calculated as previously described, and R is 18·3 tons per square inch.

The experimental value of this ratio of the increase of stress to the nominal stress, *i.e.*, $\frac{R - R_1}{R_1}$ was calculated for each of the specimens. From the theoretical formula of Professor Inglis, these values should be approximately equal to $2\sqrt{\frac{d}{\rho}}$, but the experiments show that this is very far from being the case.

If it is assumed that $\frac{R - R_1}{R_1}$ is proportional to $\sqrt{\frac{d}{\rho}}$ we may modify the equation by writing

$$\frac{R - R_1}{R_1} = c\sqrt{\frac{d}{\rho}}$$

where c is an experimental coefficient. The values of this coefficient c $\left(i.e., \frac{R - R_1}{R_1}\Big/\sqrt{\frac{d}{\rho}}\right)$ were calculated for each scratched specimen, and an examination of these values shows that in the case of the 72 deg. V-notch, c varies from 0·133 when d is 0·00067 in. to 0·184 when $d = 0·00244$ in., the average value being about 0·155. This variation in c is discussed later.

While the expression $\frac{R - R_1}{R_1}$ shows the ratio of the increase of stress to the nominal maximum stress, the decrease in strength due to the presence of a scratch is given by the corresponding expression $\frac{R - R_1}{R}$. This expression multiplied by 100 gives, therefore, the decrease in strength expressed as a percentage of the original strength of the material.

In order to plot the curves in Figs. 6 to 9, a first* assumption was made that the value of the coefficient c would be approximately constant over the small range of depths used in the tests upon the 120 deg. and the 72 deg. V-notches, and that the discrepancies in the tabulated values of c were due to experimental errors. The values of c when plotted against d, as in Fig. 10, showed no very evident law of variation, until the specimens with the larger grooves were tested. Accordingly the data were plotted in Fig. 7, with values of $\frac{R - R_1}{R_1}$, as ordinates, and values of $\sqrt{\frac{d}{\rho}}$ as abscissæ. The results for the two types of groove lay reasonably close to the straight lines A and B through the origin—so that it appeared, for a small range in the depth, that the ratio of the increase of stress to the nominal stress was approximately proportional to $\sqrt{\frac{d}{\rho}}$ as indicated by theory. The slopes of these lines give the mean values of c for the two notches, *i.e.*, for the 72 deg. V-notch $c = 0·155$, and for the 120 deg. V-notch $c = 0·0925$.

Regard was paid chiefly to those specimens which broke at the first loading, and to those which were not broken after 6,000,000 alternations under the first loading. The other specimens, which were subjected to gradually increasing loads as described above, appear to agree within reasonable limits with these results, and the fatigue strength does not appear to have been raised by the method of testing. In one test only is any marked effect apparent—S.20—where the fatigue stress appears to be raised to 18·8 tons per square inch, which is a higher result than that adopted as the strength of the unscratched material.

The curves A and B, Fig. 7, are repeated to a smaller scale in Fig. 8.

The curves A and B in Fig. 6 were drawn to correspond with the straight lines A and B of Fig. 7, values of R_1 being there plotted against $\frac{d}{\rho}$.

Similarly in Fig. 9, where values of $\frac{R - R_1}{R} \times 100$ were plotted against $\frac{d}{\rho}$, the curves A and B which were drawn again correspond with the curves A and B in Figs. 6 and 7.

In order to compare the experimental results with the theoretical equation for semi-elliptical grooves, and with the results deduced by Dr. Griffith from his soap-film experiments, curves C, D and E were plotted in Figs. 6, 8 and 9.

Curve E, in Fig. 8, shows the theoretical value of $\frac{R - R_1}{R_1}$, for semi-elliptical grooves, *i.e.*, $2\sqrt{\frac{d}{\rho}}$, and assuming $R = 18·3$ tons per square inch, the corresponding values of R_1 and of $\frac{R - R_1}{R}$ were

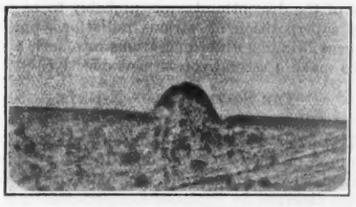


FIG. 11. MACHINE TOOL SCRATCH. × 300.

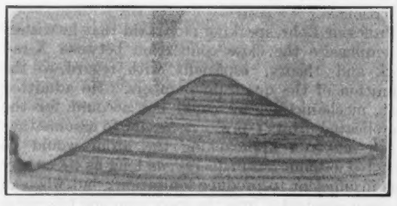


FIG. 12. DIAMOND SCRATCH. S. 22. × 300.

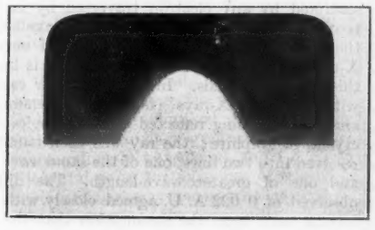


FIG. 13. S. 25. DIRECT PROJECTION. × 50.

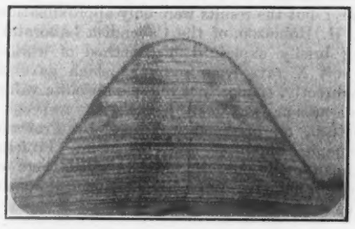


FIG. 14. S. 25. GELATINE CAST. × 100.

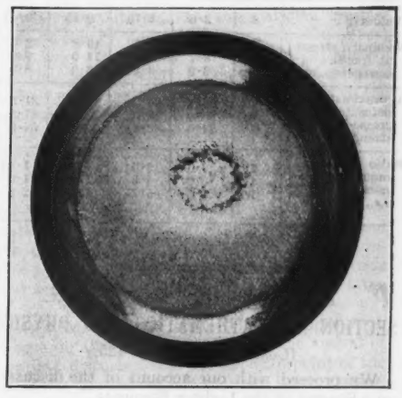


FIG. 15. FATIGUE FRACTURE SHOWING DEEP GROVE. × 4.

* See later for further remarks upon the variation of c.

calculated for various values of $\frac{d}{\rho}$ and plotted to give curve E in Figs. 6 and 9.

For the curves C and D, in Fig. 8, values of $\frac{R - R_1}{R_1}$, for 72 deg. and 120 deg. V-notches were calculated from data obtained by interpolation from the published* results of Dr. Griffiths' experiments (*vide* Table I).

R being assumed as 18·3 tons per square inch, as before, the values of R_1 and of $\frac{R - R_1}{R}$ for various values of $\frac{d}{\rho}$ were then calculated, and plotted in curves C and D, Figs. 6 and 9.

It will now be seen that there is a considerable discrepancy between the experimental and theoretical results. A few approximate figures are abstracted from the results to illustrate this. For convenience a column is also added for the larger size grooves which will be discussed later. A view of one of the fractured test-pieces is given in Fig. 15.

Table II.

—	Values of $\frac{d}{\rho}$	Theoretical Semi-Elliptical Groove.	Soap Film Experiments, 72 Deg. V.	Present Experiments.	
				72 Deg. V. (Small.)	68½ Deg. V. (Large.)
Values of c ..	4	2·0	1·75	0·15	0·45
Nominal stress at fracture in tons per sq. in.	1	6·1	6·1	15·8	12·6
	4	3·7	4·0	14·0	9·6
	7	2·9	3·2	13·0	8·3
Approximate percentage decrease in strength	1	66·7	66·7	13·5	31·5
	4	80·0	78·0	23·5	47·5
	7	84·0	82·5	29·0	54·5
Ratio of maximum stress to nominal stress i.e., R/R_1	1	3·0	3·0	1·16	1·45
	4	5·0	4·5	1·31	1·9
	7	6·3	5·7	1·42	2·2

(To be continued.)

THE BRITISH ASSOCIATION.

SECTION A.—MATHEMATICS AND PHYSICS.

(*Continued from page* 425.)

We proceed with our account of the discussion on "Spectra of the Lighter Elements."

High-Frequency Spectra and Atomic Structure.

The contribution to the discussion by Dr. D. Coster, a young physicist from the Netherlands, at present one of Professor Bohr's distinguished collaborators, had originally been set down for the Thursday morning in Section B, but was transferred to Section A to give him more time. The work of Moseley, Dr. Coster pointed out, had shown that the Röntgen spectra were far more simple than the optical spectra and all consisted indeed of a few lines which shifted more and more into regions of higher frequency with higher atomic numbers. They did this in so regular a fashion as completely to mask the periodicity of the chemical, physical and optical properties of the elements. Moseley's K and L radiations of the various elements all fell on straight lines diverging with higher atomic weights. That was correctly interpreted to signify that the X-rays belong to the inner electrons which in general form closed groups, whilst the chemical and optical properties depend upon the more loosely-held outer electrons. But further consideration indicated that the periodicity must be traceable also to X-ray spectra, and experiments by Siegbahn and others proved that Moseley's straight lines were only first approximations. Dr. Coster's tables and diagrams, largely based upon his own work, showed K, L, M, N, O, P radiations, each consisting of several rays. His energy levels T/R (where T is the spectral term as explained in the presidential address and R is the Rydberg constant) have large ranges. His T/R values for the K radiations, decrease with descending atomic numbers from 8,477 (for uranium) down to 95·8 for magnesium, while the values for the various O radiations decrease from 26 and 5·8 (for uranium) down to 0·1 for antimony. These rays have not yet been traced into regions of lower atomic weights. Plotting these T/R values (or their square roots) against decreasing atomic numbers, Dr. Coster obtains sheaves of curves, not straight converging lines of uniform slope, such as Moseley had obtained, but bent lines of changing slopes, sometimes with horizontal portions.

The conclusion he drew was that the typical periodicity of chemical properties and optical spectra is due to the circumstances that the effective (or azimuthal) quantum numbers k change little in the outermost electrons (generally 1 or 2) when we pass from an element in one group to its homologue in the next group (*e.g.*, from sodium to potassium in the alkali metals), whilst the properties disclosed by Röntgen analysis depend chiefly upon the inner electrons which form closed groups of a constant number of n (principal quantum number) in each group. These inner electronic groups are mostly completely formed and repeat in all the following groups. There is hence little indication of any periodicity, except in cases where groups are in the process of completion, *e.g.*, in the neighbourhood of the iron family, the palladium family, the platinum family, and the family of the rare earths. The occurrence of the rare earths family is connected with the appearance of electrons in orbits $n = 4$ and further orbits, and shows itself in the M, N, O radiations.

Professor Bohr, speaking next, said that he wished to emphasise the close connection between X-ray work and theory, especially with regard to the definition of the quantum numbers. He admitted that, mechanically, we could not account for the complicated orbits; it was necessary to assume that a free electron approaching the atom would be reflected without loss of energy, as long as its energy was insufficient to produce ionisation; but when an electron penetrated into the space common to several orbits, long ellipses and circles, there would be interaction between the electrons. The two quantum numbers sufficed to justify the orbits on general grounds: but the results were only approximations.

Mr. H. Robinson, of the Cavendish Laboratory, having briefly explained his method of working with soft X rays from sodium, which gave the levels directly, though not reliable absolute values, the discussion was continued, with respect to magnetism, on mathematical lines by Professors Lindemann, Ehrenfest and Langevin. Professor McLennan finally put a question to which there was no answer, namely: What would happen if another nucleus came within range?

Weak Magnetic Fields and the Polarisation of Resonance Radiation.

In a paper by himself and Dr. A. Ellett, Professor R. W. Wood, of Baltimore described a continuation of experiments brought before the Edinburgh meeting in 1921. He placed a drop of mercury in a quartz bulb and passed a beam of polarised mercury light through the mercury vapour above the drop; resonance fluorescence was set up in the vapour even when cooled to — 50 deg. C., so that the vapour pressure would only be 0·0001 mm. This luminescence was polarised to the extent of 90 per cent. also when passed into a further quartz vessel containing mercury vapour. But the experiments were not confirmed by others, nor by Professor Wood himself, when repeated under rigorously the same conditions. He finally discovered that the orientation of the magnetic field had an unsuspected strong effect; a field of 1 or 2 gauss destroyed the polarisation, and even the weak terrestrial magnetic field reduced it by one-half when acting in certain directions. Similar experiments with sodium vapour showed that such vapours were much less sensitive to the magnetic action, fields of 100 gauss being required to destroy the polarisation. Studying the phenomena with different directions of the field and of the electric vector of the exciting light, Professor Wood concluded that the molecules must undergo orientation in the magnetic field.

Magnetic Rotary Dispersion.

Mr. R. W. Roberts, of Liverpool, reading a paper on "The Magnetic Rotary Dispersion in Certain Paramagnetic Liquids," pointed out that the presence of iron salts in aqueous solutions was known to diminish the magnetic rotation of the solvent. That peculiarity of iron salts was found to be shared by the salts of cobalt at ultraviolet frequencies, but not by nickel salts. The effect might be due to some dispersive action of cobalt salts in the visible and ultraviolet regions of the spectrum; but this assumption was not confirmed by experiments, so that the depression in the magnetic rotation exhibited by aqueous solutions of cobalt salts seemed to be a true paramagnetic effect superimposed on the usual positive rotation explained by the Hall effect.

X-ray Absorption and J-Discontinuities.

Professor G. G. Barkla, F.R.S., presented a paper by himself and Miss White, dealing with certain discontinuities observed when the gas pressure in an X-ray bulb was reduced. There was in general an increase in the penetrating power of the rays emitted, but under certain conditions the absorption exhibited a novel discontinuity, rising abruptly to a higher level and then falling off again. This peculiar discontinuity set in at higher frequencies and penetrating powers with higher atomic numbers of the absorbing element. The change was not large; but the effect depended upon certain critical conditions not yet cleared up; there was either full change or no change, and the effect was not observed in experiments with Coolidge tubes. The explanation of the discontinuity was probably to be found in a superposition of various radiations, one constituent bringing absorbing atoms into such a state as to make a second constituent effective.

The Scattering of X-Rays.

The full title of a paper by Professor G. Darwin, F.R.S., was "The Recent Work of Professor A. H. Compton on the Scattering of X-Rays." Professor Darwin suggested possible explanations for some effects observed by Professor Compton, of St. Louis. Professor Compton considers that the theory of scattering of J. J. Thomson, supported by the early experiments of Barkla, does not suffice. The energy scattered by any electron traversed by an X-ray beam should be independent of the wave-length of the incident rays; but in the case of very hard X-rays and γ-rays the energy scattered is less than this theory demands. In the particular case dealt with, uniform X-rays (from molybdenum) were analysed by being reflected at right angles from a crystal of graphite; the ray was then found to be resolved into two lines, one of the same wave-length and one of greater wave-length. The difference observed of 0·022 A. U. agreed closely with calculations made upon the assumption that the longer waves were emitted by loosely-bound electrons free to recoil from the momentum of the scattered X-ray quantum, while the other waves were due to firmly-bound, non-recoiling electrons. Professor Darwin was not satisfied with this explanation and made various suggestions amounting to a compromise between the classical theory and the quantum theory, a suggestion that neither Professor Bohr nor Professor P. S. Epstein would accept, whilst Lord Rayleigh saw in the experiments a confirmation of his observations on the polarisation of the light of the sky. Professor Darwin also hinted that it looked as if an electron knew in some way whether or not an oncoming radiation was monochromatic.

Constitution of the Elements determined by the Anode Ray Method.

Dr. F. W. Aston, F.R.S., gave an account of the "Determinations of the Constitution of the Elements by the Method of Accelerated Anode Rays." He pointed out that the cathode-ray bombardment was unsatisfactory when we had to deal with elements of extremely-low vapour pressures. He had therefore developed the anode method first used by Gehrcke and Reichenheim, and then by J. J. Thomson. When the powdered substance, mixed with graphite, was put into an iron tube so as to form a perforated plug, anode rays of constant direction could be obtained. The difficulty of the method was the instability of the discharge. To overcome the instability he sent the anode rays through a kenotron tube so worked that very swift rays and currents of not more than 1 milliampere at 20,000 volts or 30,000 volts would pass steadily

* "Report on the Materials of Construction used in Aircraft and Aircraft Engines." Professor C. F. Jenkin, page 13.

for an hour and more, whatever the discharge from the anode might be. Dr. Aston said that he did not really know how his apparatus worked. But he had been able to determine the masses of the metals scandium, titanium, vanadium, chromium, manganese, cobalt, copper, gallium and germanium (whose atomic numbers rise from 21 to 32) and further of strontium (38), yttrium (39) and silver (47). Copper, gallium and silver had an isotope each, and germanium had two; all the others were single elements. The atomic weights of these elements, with the masses of their isotopes in brackets, were: Copper 63·57 (63, 65), gallium 69·72 (69, 71), germanium 72·5 (74, 72, 70), silver 107·88 (107, 108), the isotopes being arranged in decreasing order of their relative proportions. Zirconium, molybdenum, cadmium, barium and lead did not give satisfactory results. It was noteworthy that odd atomic numbers always went together with odd atomic weights; the observed deviations of the masses from integers were small, but some of his lines were not very distinct.

Triatomic Hydrogen.

During his early researches on positive ray analysis Sir J. J. Thomson obtained evidence of the apparent existence of a body of mass 3, possibly a triatomic hydrogen. The compound was a puzzle to the chemists, and its existence is controversial. Mr. G. Stead and Miss B. Trevelyan, of the Cavendish Laboratory, presented a paper on the subject, and had added a note of interrogation to its title: "The Production of Triatomic Hydrogen (?)" They submit hydrogen to an intense electronic bombardment in a cylindrical thermoionic tube provided with an open grid, but without anode. With a grid potential of 30 volts and more they observe a blue glow near the filament, showing the primary and secondary hydrogen lines. The glow spreads along the tube, and the current rises for a time; then follows a sudden fall in the current, and the glow recedes, leading to an oscillation of the glow and of the current as well as of the pressure, the latter following the current variation. Mr. Stead suggested that a polymerised modification of hydrogen was periodically formed and decomposed again during the discharge. When he surrounded the tube with liquid air, the oscillations stopped, and nearly all the gas disappeared; on removal of the liquid air, the gas reappeared, but it was decomposed by the electric discharge, the volume increasing from 1 to 1·5. The decomposed gas showed the bright primary and secondary spectra of hydrogen; but no compound could be isolated, and Mr. Stead was very doubtful as to the existence of triatomic hydrogen. Our readers may remember that Sir J. J. Thomson has suggested the possibility of the formation of evanescent compounds even of the inert gases under the intense bombardment in discharge tube; but he has also expressed doubts as to his H_3. He was not present at this particular discussion.

High Temperature Research.

On behalf of Mr. I. O. Griffith, of Oxford, who was not able to attend, Professor F. A. Lindemann made a brief communication on the continued "Experiments on Very High Temperatures" of Mr. Griffith. These experiments on the variation of temperature of the carbon arc with pressure had, Professor Lindemann stated, brought out some curious effects. The temperatures were estimated by observing the increase in the arc brightness and determining the displacement of the wave-length λ of maximum intensity. By measuring a large number of these λ under different conditions and determining the ratio of λ_1/λ_2, the ratio of the two temperatures T_1/T_2 could be deduced. Assuming the temperature of the carbon arc at atmospheric pressure to be 4,200 deg. K. (on absolute scale) the following temperatures were estimated for pressures of 6, 18, 33 and 80 atmospheres: temperatures of 4,680 deg., 6,180 deg., 6,500 deg. and 8,620 deg. K. All these temperature values were minimum estimates. Particulars were not given, as the hour was late.

The Angle of Contact.

Mr. R. Ablett, of Liverpool, described some experiments on "The Variation of the Angle of Contact with Relative Motion of Solid and Liquid." He makes use of solids in the shape of cylindrical rods. When a cylinder was partly immersed in a liquid with its axis horizontal, to such a depth that the liquid surface was horizontal right up to the cylindrical surface, the tangent at the line of contact made—he said—an angle with the horizontal equal to the angle of contact θ. The value of θ was found to be 104° 34′ (± 5′) for a cylinder of paraffin wax in water at 10 deg. C. On rotating the cylinder the angle decreased towards a minimum θ_2 on the side emerging, and increased to a maximum θ_1 on the other side of the cylinder, such that at any speed $\frac{1}{2}(\theta_1 + \theta_2) = \theta$. Beyond a critical speed of 44 mm. per second, θ_1 was found to have the constant value 113° 10′ and θ_2 the value 96° 0′. These results, Mr. Ablett thought, accounted for the discrepancy observed in the values of θ as obtained by different methods; the figures usually given were values intermediate either between his θ and θ_1, or between his θ and θ_2, according to the method employed.

Liquid Jets.

The memoir of Senator Vito Volterra, For. Member R.S., of Rome, on "Liquid Jets," was read by him in the spacious (but unfortunately very noisy) Art Theatre. He spoke in French. He pointed out that the case of liquid movement considered so far had been that of movements parallel to a plane, and the theory of functions had been used. In his research some problems of the symmetrical and unsymmetrical, not plane, movements of jets were solved, that is to say, three-dimensional problems. The treatment of the subject was strictly mathematical, and both Sir Joseph Larmor and Professor Horace Lamb, in thanking Professor Volterra for his communication, confined themselves entirely to complimentary remarks, without indicating the scope and bearing of his researches. Professor Lamb remarked that Volterra's work constituted a great advance on the researches of Kirchhoff, Helmholtz and Rayleigh. An abstract of the memoir is to be published in the British Association Report, for which we shall have to wait some months.

Series in Magnetic Disturbances.

This paper by the Rev. A. L. Cortie, S.J., of Stonyhurst, dealt with the magnetic disturbances of March 24, 1923, which was remarkable in several respects. Though accompanied by unusual earth currents and displays of aurora borealis, the disturbance fell into a period almost of minimum solar activity. The extreme ranges of the declination observed, Father Cortie stated, was 66 minutes of arc, that of the horizontal force was 238 γ, and the disturbance was indeed the greatest recorded since the exceptionally-violent storm of May 13 to 15, 1921. This year's storm was preceded, at an interval of 26 days, by the somewhat lesser disturbance of February 26, which was likewise coincident with disturbed earth currents and auroral display, while further disturbances had followed, at a mean interval of 27·2 days, the whole series extending from January 30 to June 13. Since the beginning of the year the sun had been almost free from sun-spots and bright faculæ, 70 per cent. of the 98 days of observation having been spotless, while the mean area of such spots as had been observed had covered not more than 32 parts in 1,000,000 of the solar disc. The faculæ, moreover, were very faint, though extensive.

Only one small spot in (latitude — 6 deg. and longitude 3·2 deg.) observed from April 19 to 29, seemed to be connected with this series of magnetic storms, but this spot and the faculæ marked a region of the sun's surface which had intermittently been disturbed since November, 1922. The recent series of magnetic disturbances seemed to be a continuation, at each synodical rotation (with one exception), of a long series since October 27, 1921. The mean interval of 27 days corresponded to a mean daily rotation in arc on the sun at 14·32 deg., which would be the rotation period for latitude ± 8·7 deg. (adopting Carrington and Spoerer's formula). The mean value of the longitude of the sun's central meridian for all the days of this long series was 336·6 days, while the mean value of the intermittent solar disturbance was latitude — 6·1 deg. and the longitude 345·5 deg. There was hence complete accord between the series of solar disturbances and the series of magnetic disturbances, and it would thus appear that a definite region of the sun could affect the earth magnetically even when there were no visible disturbances on it.

Professor Fowler and others put questions, but there was not any more time for an adequate discussion of this important communication than there was in many other cases. We should mention that the Section made an excursion on the Saturday of the Association week to Stonyhurst. This proved most instructive and enjoyable. Many of the original photographs and curves, shown in the Section on various occasions, and due to the late Rev. W. Sidgreaves and to the Rev. J. P. Rowland and Rev. A. L. Cortie could be examined, together with other evidence of the valuable scientific work done at Stonyhurst. There were no other astronomical papers this year.

Seismological Investigations.

The twenty-eighth Report of the Committee on "Seismological Investigations" was presented by the chairman, Professor H. H. Turner, F.R.S., of Oxford, who had drawn it up. The secretary of the committee, Mr. J. J. Shaw, of West Bromwich, afterwards added some remarks. The report deplores the death of Professor C. G. Knott, who had been associated with the work of the committee since 1883, when he became a colleague of John Milne in Japan; his investigations of the path of earthquakes had been the starting-point of the inquiry into the depth of earthquake foci. The expenses of publishing the International Seismological Summary and other expenses, the report stated, were only partly covered by the subsidy from the International Union for Geodesy and Geophysics, and by the annual grant of 100*l.* from the Caird Fund of the British Association and the special grant of 200*l.* from the Royal Society. Thanks to the generosity of Dr. J. E. Crombie, Mr. J. S. Hughes, B.A., of New College, Oxford, was now able to give his whole time to the work at Oxford. Of the new Milne-Shaw machines supplied to Stonyhurst, Strasbourg, Ottawa, Hong Kong, Hyderabad and Perth (Australia) only one belonged to the committee; the machine sent last year to Christmas Island for the eclipse observation had arrived too late.

As regards depth of focus, valuable information had been obtained from the study of the arrival of the earliest disturbance at the opposite point of the path, as was pointed out last year (see ENGINEERING, October 6, 1922, page 421). The seismic disturbance took 21 minutes to travel right through the earth. A posthumous paper by the late Prince Galitzin indicated the existence of three critical surfaces in the earth at depths of 106 km., 232 km., 492 km. (that is, at 0·017, 0·036 and 0·077 of the earth's radius); these figures were based on measurement of the angles of emergence and were independent of the investigation of focal depth. As regards the recurrence of shocks, a period of 21 minutes had first been observed in the Jamaica earthquake; other analyses pointed to further earthquake periods of four years, fifteen months and six months. The 21-minute periodicity had induced Dr. Jeans to reinvestigate the whole question of earthquake propagation, and he had arrived at the conclusion that there were two further waves in addition to the Rayleigh waves L. Accepting the velocities at which the Oppau explosion waves seemed to have been propagated, these waves would return to the epicentre after periods of 116 minutes and 222 minutes respectively, and there was evidence that they might act as triggers for new shocks.

Professor Turner also displayed some seismograms of the terrible Japanese earthquake of September 1. The main shock had, apart from tremors, been followed by another violent shock within 23 hours 48 minutes, a figure which confirmed the 21-minute period. It is well-known that the earth has been disturbed ever since, and several further earthquakes were recorded by Milne-Shaw machines during the meeting. Mr. Shaw then pointed out that great earthquakes had shaken the Pacific shores during recent years, near Kamschatka, Alaska, Chili and Japan; something might happen on the Tonga Islands, another unstable district; but this statement of Mr. Shaw's must, of course, not be misinterpreted into a prediction

of a Tonga earthquake. We should like to add a few words about Mr. Shaw's automatic seismograph bell. In this device a thin arc-shaped wire is attached to the boom of the machine so as to be close to a mercury cup; the cup is shifted by means of a divided screw head until the wire just touches the mercury, thus closing the bell circuit; the screw is then turned through a small angle, so that contact is broken and the wire remains within a small fraction of a millimetre of the mercury meniscus. When the bell has rung, owing to the registration of a disturbance, the device has to be set again by hand.

Tides and Meteorological Fluctuations of Sea Level.

The report of the committee appointed to assist work on the Tides (chairman, Professor H. Lamb; secretary, Dr. A. T. Doodson) was drawn up by the secretary; Professor Proudman had added an Appendix. Both these gentlemen are at the Tidal Institute, Liverpool, which is doing exceedingly useful work. With the aid of the Meteorological Office they are able, for instance, to send out corrections to the tide tables, which are of great service to Harbour Boards and to vessels waiting for sufficient water to cross the bars.

The "Meteorological Effects on Sea Level and Tides" were explained by Dr. Doodson in a paper of this title. At Liverpool, Dr. Doodson stated, the static effect of the atmospheric pressure distribution and the operation of the resulting wind might alter the sea level by 3 ft. and more. The greater part of the effect would quantitatively be expressed by the relation $\zeta = \kappa B + \lambda E + \mu N$, where the Greek letters represented constants, and B, E, N denoted the local atmospheric pressure and its gradients East and North. The correlation between fluctuations of sea level and atmospheric pressure was greatest when the sea level was taken 3 hours earlier than the barometer reading, whilst the correlation between sea level and the easterly gradient, corresponding roughly to a south wind, was greatest when the mean sea level was determined 15 hours after the corresponding E. For the northerly gradient (easterly wind) the time difference for maximum correlation was practically zero. At Liverpool a S.W. wind (not a wind blowing directly into the Liverpool Bay) was most effective in raising the sea level, and the winds in the Atlantic were 50 per cent. more effective than the winds in the Irish Sea for a given pressure gradient; the most effective wind for level raising was at Liverpool almost due south when operating in the Atlantic, and almost due west when operating in the Irish Sea. On the British Coast of the North Sea the most effective wind directions for raising the sea level were also from the west (*i.e.*, off shore). The local configuration of the coast line played only a small part in this phenomenon. For the effect of the winds on the height and the time of high water no simple law had so far been formulated.

The report of the committee already mentioned dealt mainly with "residues" of unknown origin. Friction, it is pointed out, introduces harmonic constituents which are not in the original tidal motion or among the ordinary "shallow-water constituents." That was first suggested by Professor Proudman, and put to the test at Newlyn; there, however, it proved too difficult to separate this frictional effect from other larger perturbations. But the study of the tides at St. John, in New Brunswick, on the Bay of Fundy, proved more instructive, and the investigation was being continued with the assistance of Dr. Bell Dawson, Superintendent of the Canadian Survey of Tides and Currents.

Energy of the Circulation of the Atmospheres.

Assuming the general circulation of our atmosphere to consist of a west-east circulation round the north pole and an east-west circulation about the equator, the dividing zone lying near latitude 40 deg., the total energy of the general circulation, Captain D. Brunt, of the Air Ministry, explained in a paper of the above title, had been estimated at 3×10^{27} ergs. The energy of a cyclonic disturbance would be additional; the kinetic energy of the cyclone which developed over the North Sea between July 27 and August 3, 1917, had been estimated by Sir Napier Shaw at $1{\cdot}5 \times 10^{24}$ ergs, which represented an addition to the general energy of 50 per cent. over the area covered. Discussing the dissipation of this energy by turbulence and friction, Captain Brunt calculated that the atmosphere would be brought to rest within $1\frac{1}{6}$ day and that its kinetic energy would be reduced to one-tenth of its original value within three days, if this rate of dissipation were maintained. But the conversion of a little more than 2 per cent. of the effective incoming solar radiation energy into kinetic energy of motion would be sufficient to maintain the level of the kinetic energy of the general circulation. The mechanism of the conversion was not understood. But, following a suggestion made by Sir N. Shaw, Captain Brunt calculates that the necessary energy would be converted into work if only 10^{11} grammes of air were to be raised somewhere on the equator, and heated to a sufficient potential temperature to rise to a height of 15 km. at the rate of 0·1 cub. km. per second, and were then to drift polewards, losing heat by radiation until the air could descend to sea level in latitude 60 deg. An astonishingly small amount of air convection would thus be able to maintain the energy of the general circulation.

Navigation.

Lectures and demonstrations were given on the afternoons of the Thursday and Friday of the meeting. In the first of these lectures Dr. W. M. Smart, of Cambridge Observatory, discussed "Navigation" with special reference to the use of scientific instruments and methods. He pointed out that dead reckoning might lead to serious errors, a fact which was not sufficiently recognised, and he advocated the use of radiotelegraphy for position finding. He exemplified his preference by a detailed reference to the Battle of Jutland, where, owing to errors in the position of the reporting ships, the British fleet had encountered the German fleet 15 miles ahead of the expected spot.

Alternating Magnetism. The Frenophone.

The other lectures and demonstrations concerned novel instruments and researches which have recently been noticed in our columns. Mr. W. M. Mordey, lectured on "Some Recent Studies in Alternating Magnetism," adding several new striking experiments to those we illustrated on page 671 of our issue of June 1 last. The "Frenophone," or "Friction-Operated Loud Speaker" of Mr. S. G. Brown, F.R.S., was mentioned among the exhibits of the Royal Society Soirée, of last May, on page 661 of our issue of May 25.

Mathematical Papers.

In their "Notes on the Approximate Expression of Empirical Results," Professor H. Levy and Mr. W. H. Moore, of the Imperial College of Science, South Kensington, pointed out that, if it were experimentally possible within a given range of a variable to record only a very limited number of observations, a question would arise as to the positions of this range at which it would be desirable to take the readings so as to deduce the best approximation to the curve which was lying evenly among the points. These positions might be found by a simple combination of known methods. For cases when it was desired, in the determination of a simple finite expression, to represent the values of a function and its derivatives to certain relative degrees of accuracy over a finite range, or to find such an expression for the solution of a differential equation, Professor Levy indicated a simple modification of the method of least squares as an effective and convenient way of dealing with the problem.

Apocoptic Expansions.

A paper having this title, read by Mr. T. Smith, M.A., of the National Physical Laboratory, concerned the expansion of a general function, as by Taylor's theorem, in which it is customary to consider a number of leading terms and to find limits between which the remainder lies for a definite range of the independent variables. The expansion is called apocoptic (cut off) because the number of terms is a predetermined finite integer and not infinitely great as in the expansions of mathematical analyses. The polynomical obtained, Mr. Smith said, was in general not the closest representation of the function, the expansion, like formulæ for numerical interpolation, representing curves of the order n which passed through $(n + 1)$ points of the fundamental curve. The highest possible accuracy was obtained when the curve was made to pass through $(2n + 2)$ points not lying on the fundamental. Mr. Smith had cast his paper in a pure mathematical form. The method would be useful in the numerical tabulation of functions which could be calculated from a smaller number of terms than in the expansion now in use. It would further facilitate the mechanical design of instruments. The best possible balance of aberrations in an optical instrument for a given aperture and field could by this method be deduced, for instance, in cases when there were three independent variables and when manufacturing limitations, such as restriction to spherical refracting surfaces, had to be taken into consideration. Information was thus obtainable on the permissible departures from the spherical form for future developments and on the nature of the problems to be faced by the optician.

(To be continued.)

THE GAS ENGINE POWER STATION OF PALMERS' SHIPBUILDING AND IRON COMPANY.

(*Concluded from page* 366.)

Before concluding our description of this interesting gas-driven power station we propose to give some details of the switch gear installation which embodies points of special interest. As previously explained, the seven 1,500-b.h.p. National gas engines each drive a 1,000-kw. 6,600-volt, three-phase 40-period alternator and the 1,000-b.h.p. gas engine drives a 700-kw. 240-volt direct-current generator. Of the seven 1,000-kw. alternators the first five were supplied by the Phœnix Dynamo Company, and the last two by Siemens Brothers Dynamo Works. Both of these firms are now merged in the English Electric Company. The 700-kw. direct-current generator is by Messrs. Bruce, Peebles and Co. The alternating current machinery operates in parallel with the mains of the Newcastle Electric Supply Company, and feeds a large area, and it is this feature of the station which adds interest to the high-tension switch gear installation. The operation of a large gas engine-driven power station of this kind in parallel with the stations of a very large electric supply company is somewhat unusual and adds interest to the whole installation. In addition to feeding into the supply mains of the Newcastle Electric Supply Company, the station also feeds four works sub-stations situated respectively at the blast furnaces and in the engine works, boiler shop and steel works, a diagram of the arrangement being given in Fig. 33, on page 455. The whole of the high-tension switch gear which is diagrammatically illustrated in this figure was supplied by the Metropolitan-Vickers Electrical Company, Limited, of Trafford Park, Manchester.

The switch gear in the power house is arranged to control the seven 1,000-kw. alternators and, in addition, two 700-kw. rotary converters and three feeders, two of which serve a ring main, and the third the incoming circuit from the supply company. The switch gear was erected in the year 1915 and the original intention was that the gas engine sets should be used only for supplying the works, and the connection to the Newcastle Electric Supply Company's mains should be used only for taking a supply in the event of a number of the engines being shut down. It was not intended at any time to run the station in parallel with the supply Company's system. Under these circumstances it is obvious that unnecessary expense would have been incurred in fitting all circuits with circuit breakers capable of meeting the fault conditions which might arise on the large North-East Coast network, since connection to that network would only be made in emergency in order to keep the works going. The conditions were adequately met by fitting circuit-breakers of large interrupting capacity to the supply company's feeder and the two ring main feeders, and fitting all other circuits with breakers of smaller interrupting capacity, but capable of operating satisfactorily on a fault with only the power station

plant behind them. A duplicate bus-bar system was installed, but arrangements were made for connecting the incoming feeder from the power company to one set of bars only. Under normal working conditions all the power station generator and feeder circuits would be connected to the lower set of 'bus-bars shown in Fig. 33, but in case of stoppage of the generating plant the two ring main circuits would be connected to the upper set of bars by the selector switches. These bars would be fed from the incoming supply company's feeder, and the arrangement allowed an alternative suppy to be given to the sub-station at any time without trouble or delay, while giving the advantage of duplicate 'bus-bars for cleaning and testing purposes.

When it was decided that the station should be run in parallel with the supply company's system some modification was necessary in this original arrangement, and the conditions were met by installing a 'bus-bar coupling switch by means of which the two sets of bars could be coupled together. Provision is made so that synchronising can be done across this switch, while the switch itself is made of large interrupting capacity, and relay arrangements have been introduced so that under fault conditions this large breaker tends to open before the smaller breakers of the original gear. In the event of a fault the operation of this breaker would disconnect the two systems, the large breaker taking the brunt of the shock. If the fault were in the power-house the smaller breakers would then operate and clear it, but would not have to operate with the supply company's system behind them. The interconnection and ring-main feeder cables are in duplicate, and selector switches are fitted with horizontal barriers of moulded stone, while additional vertical barriers of moulded stone or asbestos slate are inserted between phases at points where current may be broken on open contacts, as for instance between potential transformer fuses. The cubicles are fitted with sheet steel doors both at back and front. The arrangement of the two sets of bus-bars at the top of the cubicles is well shown in Figs. 34 to 37. As will be both the solenoid and hand operation. The oil circuit breakers of the ring main and incoming feeders are of a larger capacity and are as shown in Fig. 34. In all the breakers each pole is contained in a separate oil tank which is fitted with a lining of insulating material. In the case of the smaller type of breaker the three tanks of the three-phases are bolted to a common top framework, but in the large type each pole forms a separate unit. The

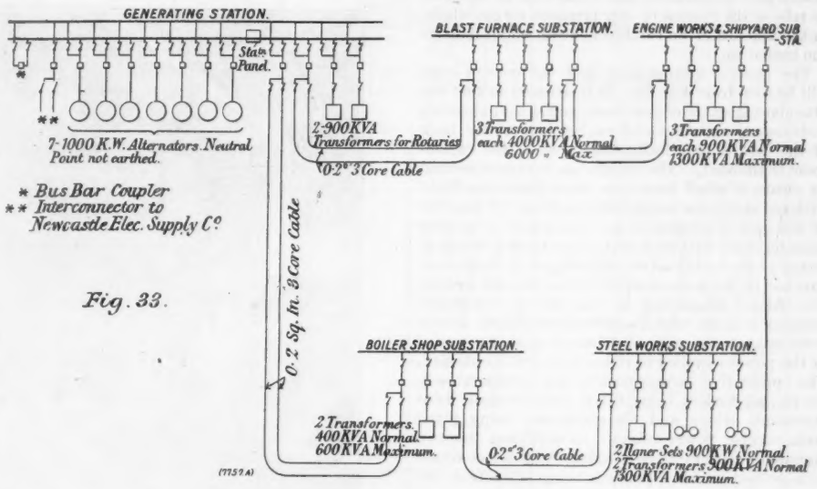

GENERATING STATION.
Stn Pand.
BLAST FURNACE SUBSTATION.
ENGINE WORKS & SHIPYARD SUB-STA.
7-1000 K.W. Alternators. Neutral Point not earthed.
2-900 KVA Transformers for Rotaries
3 Transformers each 4000 KVA Normal 6000 " Max
3 Transformers each 900 KVA Normal 1300 KVA Maximum.
0.2" 3 Core Cable
* Bus Bar Coupler
** Interconnector to Newcastle Elec. Supply Co
0.2 Sq. In. 3 Core Cable
BOILER SHOP SUBSTATION
STEEL WORKS SUBSTATION.
2 Transformers 400 KVA Normal 600 KVA Maximum.
0.2" 3 Core Cable
2 Tanner Sets 900 KW Normal.
2 Transformers 900 KVA Normal 1300 KVA Maximum.
(7757.A)

Fig. 33.

Fig. 34. END VIEW OF RING MAIN CUBICLES Nos 9 & 10.

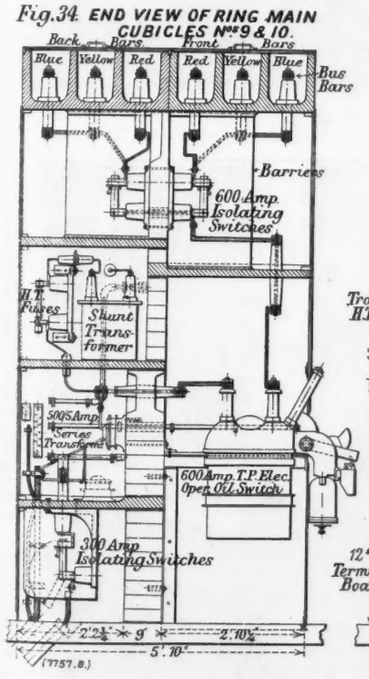


Fig. 35. END VIEW OF ALTERNATOR CUBICLES Nos 2, 3, 4, 5 & 6.

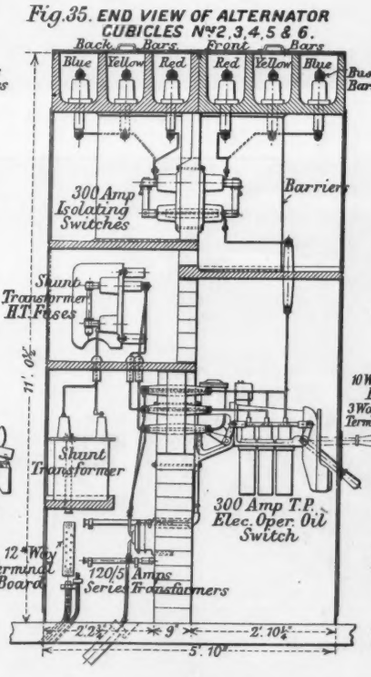


Fig. 36. END VIEW OF TRANSFORMER CUBICLES Nos 11 & 12

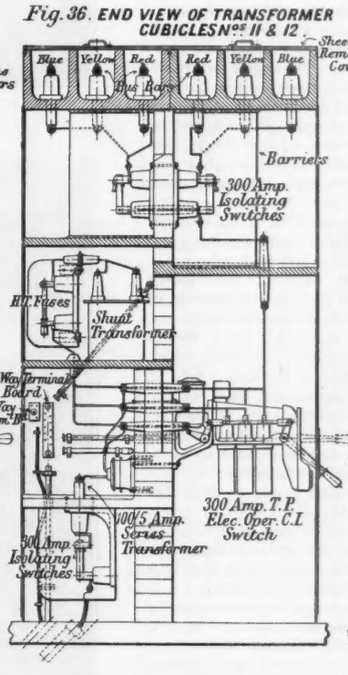
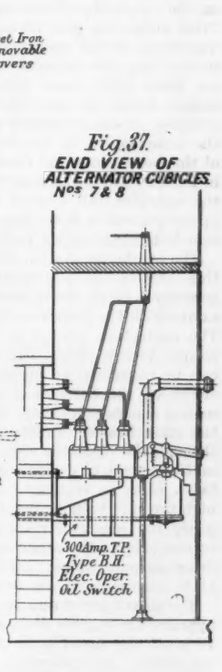


Fig. 37. END VIEW OF ALTERNATOR CUBICLES Nos 7 & 8



provided to enable either or both cables to be used. This arrangement is indicated in Fig. 33. As will be clear from this figure the ring main ensures a supply to the sub-stations *via* either of the feeder switches, and this arrangement combined with the duplication of the cables renders the total interruption of supply to any sub-station very improbable.

This 6,600-volt switch gear is of the cubicle type and is carried on a gallery in the power-house with the control desk on the floor below. Cross-sections of characteristic panels of the gear are given in Figs. 34 to 37, annexed, while a general view of the high-tension cubicles is given in Fig. 38, on page 456, and a general view of the control desk in Fig. 39 on the same page. The direct-current switchboard can be seen opposite the control desk in this latter figure. The cubicles are built of brick seen they are carried in moulded stone troughing. Porcelain stems formed on the bus-bar insulators carry the high-tension connections through the stonework, while corresponding porcelain tubes are fitted at all points where high-tension connections pass through walls or side barriers.

The oil circuit-breakers are of three different types, the five original alternator cubicles and the transformer cubicles being fitted with 300-ampere breakers as shown in Figs. 35 and 36, and the two latest alternator panels being fitted as shown in Fig. 37. The two types of breaker are of the same capacity, but the operating coil is situated in front of, instead of above, the breakers in the latter pattern. All breakers are operated electrically from the control desk, the operating handles shown in the figures serving only as a standby and for emergency work. A loose-handle feature is incorporated in three units are mounted on a common framework and coupled to one operating shaft. The top casting forms an explosion chamber above the oil, and the chambers are provided with vent pipes to carry any gases away to the outside of the cubicle, as can be seen in Fig. 34 and in the interconnector cubicle in Fig. 38. The operating control circuit is taken from a 240-volt motor generator set which is used for excitation purposes, and in case of failure of this source of supply the circuit is automatically connected to a 240-volt direct-current obtained from a local sub-station.

The isolating switches are of standard type and require no description. They are provided with locking catches to hold them closed during fault conditions. The instrument transformers are also of standard types, the series transformers being of the open type insulated for 11,000 volts and the potential

transformers being oil-immersed. Expulsion type fuses are fitted on the high-tension side of the potential transformers. The neutral point of the generating system is not earthed, and accordingly a set of static ground detectors is mounted on the end of the cubicle structure, by means of which an earth on the system can be detected. The instruments are connected to the set of bus-bars on which the station is normally working. A static discharger equipment is also connected to the bars to relieve the system of any pressure surges which, in the absence of an earthed neutral, might damage the insulation.

The general arrangement and the control desk will be seen from Fig. 39. It is situated so that the attendant faces the engine-room, and as the indicating instruments are supported on brackets at the back of the desk a practically clear view of the engine-room is afforded. The circuit-breakers are operated by means of small drum-type control switches fitted with red and green lamps which indicate the position of the switch contacts. An installation of graphic recorders and watt-hour meters provides a complete record of the total load on, and output of, the generators and of the power supplied to the various feeders. The feeder connecting to the supply company's network is fitted with two sets of watt-hour meters with ratchet and pawl attachment so that a record of the power supplied in either direction is obtained. The protective arrangements are comparatively simple, all feeders being fitted with overload fixed time-limit relays and all generators being fitted with reverse power relays. In addition, the two ring-main feeders have a leakage trip device to act as a protection when power is being taken from the supply company's system. Provision is also made on the ring-main system for the addition of Merz-Price protective gear at some future date. Speed regulation of the gas engines is carried out electrically from the control desk. The engine governors are fitted with small shunt-wound direct-current motors which are controlled by drum type control switches on the generator panels. We referred to the arrangement in the course of our description of the gas engines, and illustrated the governor gear in Figs. 28 and 29, on page 365 *ante*. The gear gives the operator full control over the synchronising operation, and he is not dependent on verbal or other signals being correctly transmitted to the driver.

The excitation system which has been adopted in this station is somewhat unusual, two motor generators being used, each of which is capable of exciting all the generators under normal conditions. The excitation voltage is controlled by a Metropolitan-Vickers automatic voltage regulator which can be connected to operate on the shunt field of either of the 240-volt direct-current ends of the motor generators. Any variations in voltage on the main bus-bars influence the excitation voltage through the regulator with the result that an automatic increase or decrease of the main field currents takes place as required. This tends to keep the high-pressure voltage constant. In case of emergency the generator main fields may be connected to one side or the other of the 480-volt three-wire direct-current system. When working in this way all voltage regulation is carried out by hand.

The direct-current switchboard is placed directly opposite the control desk, as can be seen in Fig. 39. It is of the usual type and controls the rotary-converters, direct-current generator and various feeders. In view of the fact that they are situated in a gas-driven power station, all apparatus on the switch boards are given a black oxide finish instead of the more usual polished nickel. This makes a desirable and lasting finish for the board in situations of this class. The rotary converters require no description, but it is of interest to note that the machine transformers have an auxiliary secondary winding from which a 440 alternating supply is taken for a lighting service in the power station.

It will be seen from Fig. 33 that of the four sub-stations three are purely transformer stations, but that the fourth controls the supply to two Ilgner rolling mill equipments in addition to containing two transformers. The high-tension switch gear in all the stations is built on the same lines and is of the type illustrated in Figs. 40 to 43, on page 457. The gear in all cases consists of self-supporting sheet steel cubicles arranged for mounting against a wall, all access to the interior being obtained through hinged doors at the front. The bus-bars are carried at the top with vertical barriers of asbestos slate between them, while similar barriers are placed between isolating switches and potential transformer fuses. All connections between the various pieces of apparatus are insulated. The gear fitted to the panels is generally similar to that employed in the generating station except that the oil circuit breakers, which are of smaller type, are hand operated. The overload coils of these breakers are operated from series transformers, and a time limit action is given by a fuse shunting the coil. A no-volt trip device is also fitted on the breakers controlling the Ilgner motor feeders. The ring-main breakers are non-automatic, but as explained above provision has been made for fitting Merz-Price protective gear at some future date. Recorders and watt-hour meters are fitted as in the power station, so that complete information about the power used in any part of the works is made available. These instruments together with the usual indicating instruments are mounted directly on the cubicle doors, as shown in Fig. 40. It may also be noted that the control equipments required in connection with the Ilgner rolling-mill gear was also supplied by the Metropolitan-Vickers Electrical Company. In concluding our description of the interesting and important station it should be said that the whole scheme was carried through to the requirements and under the superintendance of the Company's electrical staff. We have to thank Mr. Hewitson Hall, general manager of the iron and steel works, for assistance and facilities given to us in the preparation of these articles.

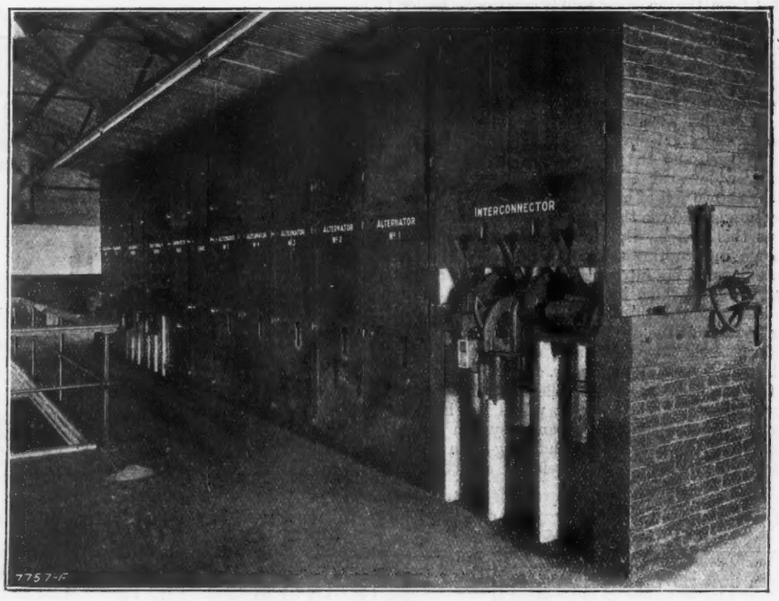


Fig. 38. High-Tension Cubicles.

Fig. 39. Operating Desk and D.C. Switchboard.

Beeston Sewerage Work.—We are informed that the Beeston (Notts.) Urban District Council has decided to consider certain alterations and extensions to their sewerage system for the purpose of relieving unemployment.

The Manchester Association of Engineers.—This association has issued a small booklet giving particulars of the meetings which are to be held in the Memorial Hall, Albert-square, Manchester, on Friday evenings, at 7 p.m., from October 12 to March 28, for the reading and discussion of papers, and other functions.

SWITCHGEAR AT PALMERS' GAS ENGINE POWER STATION.

FIG. 40. SUB-STATION SWITCHBOARD.

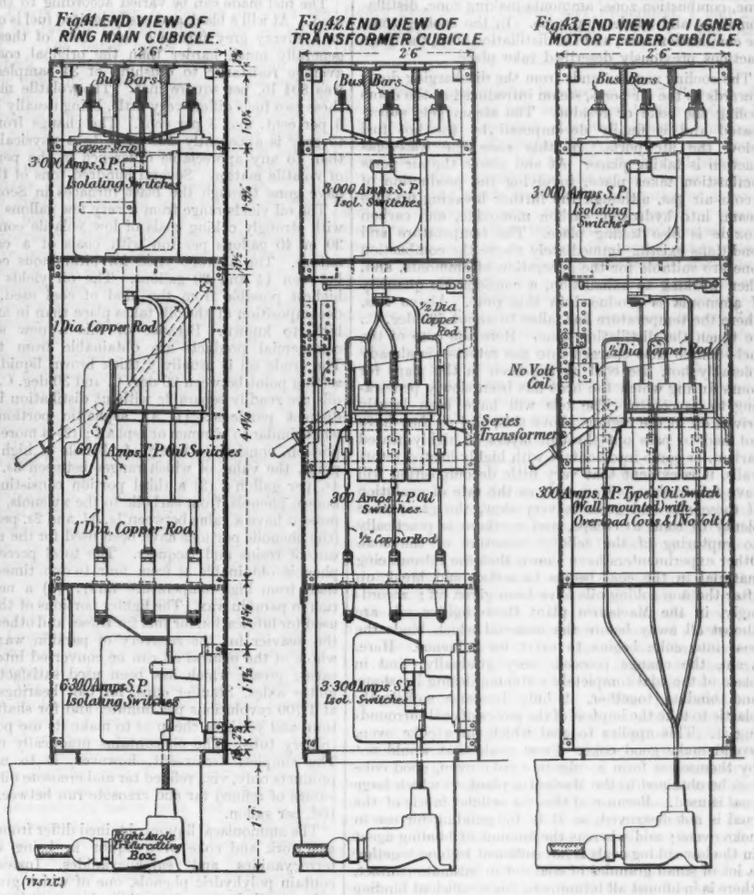


Fig 41 END VIEW OF RING MAIN CUBICLE.
2'6"
Bus Bars
Copper Strip
3000 Amps S.P. Isolating Switches
1" Dia. Copper Rod
600 Amps T.P. Oil Switches
1" Dia. Copper Rod
6 300 Amps S.P. Isolating Switches
Right Angle Interlocking Box
Fig 42 END VIEW OF TRANSFORMER CUBICLE
2'6"
Bus Bars
3 000 Amps S.P. Isol. Switches
½" Dia Copper Rod
300 Amps T.P. Oil Switches
½" Copper Rod
3 300 Amps S.P. Isol. Switches
Fig 43 END VIEW OF IGNER MOTOR FEEDER CUBICLE.
2'6"
Bus Bars
3 000 Amps S.P. Isolating Switches
½" Dia Copper Rod
No Volt Coil
Series Transformer
300 Amps T.P. Type 'A' Oil Switch (Wall mounted) with Overload Coils & 1 No Volt

REFRACTORY MATERIALS SECTION OF THE CERAMIC SOCIETY.

THE thirteenth meeting of the Refractory Materials Section of the Ceramic Society was held on October 4 and 5, in the Grosvenor Museum, Chester, the president (Mr. J. Holland) taking the chair at a large gathering of members.

Mr. T. Arthur Acton, F.S.A., F.G.S., gave a comprehensive "General Sketch of the Geology of the Chester District," the interest of which was enhanced by the use of lantern slides, specimens of rocks and minerals, maps, sections, &c. Including adjoining parts of North Wales, the surface portions were chiefly made up of post-tertiary (alluvial deposits, gravels, glacial deposits), with triassic and carboniferous formations. A drive in the afternoon over a considerable portion of the ground afforded an opportunity to members to see many of the geological features referred to. The occurrence of pockets of silica sand was alluded to, similar to those found in Derbyshire and Yorkshire.

Mr. W. J. Gardner read a paper by Mr. J. Holland and himself, on "Improvements in Drying Refractories or Other Goods." The dryer specially described consisted of two parallel chambers 60 ft. long and 3 ft. wide, with a flue passing beneath the whole length. The flue is heated by means of a furnace or by hot gases from any convenient source. At the back the bottom flue communicates with two lateral flues (one on each side) which lead to the chimney stack over the front of the dryer. A cooling chamber 10 ft. long forms a continuation of the main chamber. Two steel roller tracks run parallel along the floor of the chamber, the goods to be dried being supported on a number of plates. This stove of two chambers can dry 5,000 bricks per shift of 9 hours, using 4 cwt. coal. This system of drying improves the conditions for the employees, and the better conditions and easier facilities afforded tend to a higher quality of goods. Much time is saved, and a very much smaller ground area is required for a given output of bricks.

Dr. J. W. Mellor's paper on "The Zenith Temperature" was taken as read. From some physical data, and making certain (not unnatural) assumptions, it is calculated that the highest possible temperature is somewhat under four billion degrees Centigrade.

The last of the first day's papers was by Mr. W. J. Rees, B.Sc., F.I.C., on "Glasshouse Pots." This was a brief discussion of the difficulties more commonly met with in making and using the pots, and a consideration of the best means of overcoming these.

The first paper on the second day was by Mr. A. H. Middleton, entitled "Notes on the Proctor Dryer." The dryer at Consett described is a three-track tunnel dryer consisting of a rectangular chamber, 50 ft. long, 20 ft. wide and 6½ ft. high. It holds eight cars on each of the three tracks, the total capacity being 14,976 bricks. As in other humidity dryers in the first zone the outside surfaces of the goods are prevented from drying at a much greater rate than the inside. If bricks only were being dried the drying could be completed in 12 hours, and probably in 8 hours. Various shapes and sizes can be dried satisfactorily at the same time. Advantages claimed for the Proctor dryer are that drying, especially of difficult shapes, can be carried out much more quickly and with less risk of cracking and setting-up drying strains. As compared with a hot floor, the conditions in the moulding shop can be made much healthier and pleasanter for the workers. It also gives large savings in fuel, except where exhaust steam or some source of heat that could not otherwise be utilised can be made available for heating.

Next came a lengthy important paper by Mr. R. Maclaurin, on "New Methods of Producing Gas for Industrial Operations." In the various methods of making industrial gas, three different chemical reactions are utilised: (*a*) The distillation reaction, when bituminous coals are heated above 400 deg. C. in the absence of oxygen; (*b*) the reaction of air with large excess of hot carbon, producing a mixture of nitrogen, carbon monoxide, and a little carbon dioxide; (*c*) the water gas reaction, when steam is decomposed by red-hot carbon, forming hydrogen, carbon monoxide and some carbon dioxide. In the Mond and Maclaurin producers, a combination of these reactions takes place.

Low temperature oils are generally more liquid and browner, and altogether less pitchy than high temperature tars.

The yield of gas from coal increases as the temperature is raised, and at the same time the coal becomes fully carbonised in a much shorter time, and as gas is more valuable than the materials it replaces, it is of course made in preference. By low temperature distillation there is obtained in the gas evolved from 10 per cent. to 14 per cent of the heat of the coal; by high temperature distillation from 20 per cent. to 25 per cent.

Good producer gas may contain from 29 per cent. to 33 per cent. of carbon monoxide, and is an excellent gas where very high temperatures are required (as in steel furnaces), but is unsuitable for the ceramic industry because, in the early stages of firing, its flame might easily be put out by contact with very large quantities of cold ware. The introduction of steam with the air largely overcomes all the objections to the air type of producer.

The full-sized Maclaurin plant at Grangemouth is about 45 ft. high and 8 ft. across its widest part. It is built square rather than circular to allow of greater uniformity in the air distribution. The air blast is introduced about 12 ft. above the four discharging doors, which are themselves about 6 ft. above the ground. The blast is distributed through a large number of narrow brick ports in the side walls and also in a dividing wall which is carried across the plant for the purpose of ensuring greater uniformity in the distribution. Above these ports the plant tapers upwards until the opening is reduced to about 3½ ft. The brickwork stops here, and a cylindrical iron tank, 8 ft. wide, and about 10 ft. high, completes the main part of the structure. The bottom of this tank projects upwards towards the centre so as to provide a well in which oil and water can collect. Within this outer cylinder is placed a second cylinder, about 4 in. less in diameter. This cylinder (called the condenser) is supported about an inch from the bottom, leaving a passage for the oil. On the condenser is fixed the charging bell, and a small hopper capable of holding about a ton of coal. The plant when full holds about 30 tons of fuel. Working is continuous after the plant has been started, about 1 ton of coal per hour being put in at the top, and the equivalent of coke or residue withdrawn at the bottom.

In changing over from working for coke to working to complete gasification, the only alteration required is in the adjustment of the valve controlling the air blast and the valve controlling the gas passing away. The control of these valves enables the operator to

obtain either a black smokeless fuel, or a hard grey coke, or an ashy residue. Though continuous, the producer may be considered to be divided into five zones: Cooling zone, combustion zone, ammonia-making zone, distillation zone, and condensing zone. In the cooling zone, the combustion zone, and the distillation zone, the three reactions previously described take place.

The cooling zone extends from the discharging doors upwards to the air ports, steam introduced at the doors cooling the coke or residue. The steam gets superheated and is finally decomposed by the hot fuel below the air ports. In this zone the water-gas reaction is taking place. At and above the air ports combustion takes place, involving the production of a coke-air gas, although the further breaking up into steam, into hydrogen, carbon monoxide, and carbon dioxide is also taking place. The temperature and conditions existing immediately above the combustion zone are suitable for the generation of ammonia, and, when working to exhaustion, a considerable quantity of ammonia is produced in this zone. Above this, where the temperature has fallen to about 500 deg. C., we touch the distillation zone. Here the core of the fuel—unlike that charged into gas retorts—is already tolerably hot, the coal having been in the plant for hours during which the heat has been slowly penetrating to its centre. The oils will have been largely driven off in the regions above this, and as they have not had to pass out through layers of highly-heated carbon, or come into contact with highly-heated retort walls, it is evident that very little decomposition will have taken place. Moreover, as the rate of evolution of these oils and gases is very slow, the gases have plenty of time to escape, and so there is practically no rupturing of the cellular structure of the coal. Other experimenters have shown that the intumescing material in the coal begins to soften and break up after the non-coking oils have been given off; accordingly, in the Maclaurin plant these lighter oils are almost all away before the material which binds the coal into coke begins to exert its influence. Here, again, the change proceeds very gradually, and in place of the coal completely softening, losing its shape and binding together, it only becomes sufficiently plastic to take the impress of the pieces of coal surrounding it. This applies to coal which, in a coke oven, would make good coke. From coals that would not by themselves form a coke in a coke oven, good coke can be obtained in the Maclaurin plant, in which large coal is used. Because of this the cellular fabric of the coal is not destroyed, as it is by grinding for use in coke ovens; and whereas the amount of binding agent in the low-coking coals is not sufficient to bind together a lot of small granules of coal not in intimate contact, there is in almost all bituminous coals sufficient binding material to penetrate and bind into one structure cellular material in very close contact, as such material is in the unground coal. When the centre of a piece of coal has reached 400 deg. C., the outer layer is probably about 450 deg. C. in the Maclaurin retort, 650 deg. C. in a low-temperature vertical retort, and 1,000 deg. C. in a high-temperature vertical retort.

The oily vapours are caught in the ascending stream of hot gases as they leave the surface of the coal in the Maclaurin plant, and pass upwards to the constriction where they are moving with a fair velocity. Above this point they rapidly spread out through the comparatively cold incoming fuel, while the velocity as well as the temperature decreases quickly. Condensation of the oils, therefore, takes place, and also of water, and these condensates trickle down into the well of the condenser. Here they accumulate, passing below the inner cylinder, which acts as a seal, forcing the gases to rise through the incoming coal and down the space between the inner and outer cylinders, where further condensation takes place. After the oil and liquor in the well have once reached the level of the gas exit pipe near the bottom of the outer cylinder, gas, oil and water flow along this pipe to the hydraulic main, coolers and scrubbers, where the remainder of the oil and the ammonia and the bulk of the water are condensed out. Nothing but clean, cool gas passes to the suction fan, which delivers it to the points of utilisation. When working for coke the gas leaves the plant at between 60 and 80 deg. C., and, as the coke being discharged is also cooled, the heat losses in the process are remarkably small. The heat necessary to maintain the temperature is supplied by the combustion of a small quantity of the carbon of the fuel, but the carbon monoxide formed is afterwards available in the gas produced.

The coke generally resembles in size and appearance the lumps of coal going into the plant. The higher the coking index of the coal the more it is liable to change in appearance due to softening. In non-coking and low-coking coals a considerable quantity of the limy and pyritic bands break off and become concentrated in the dust. The large coke obtained by screening consequently often contains considerably less ash than would be anticipated from the ash in the coal used. Stony matter can also be readily separated out after carbonisation by the difference in specific gravity of the coke and stone.

The fuel made can be varied according to the blast used. At will a black and easily-ignited fuel is obtained or a silvery grey furnance coke, both of these being generally much harder than the original coal. The average resistance to crushing of 34 samples tested was 804 lb. per square inch. The volatile matter in these two fuels differs very little, being usually between 5 per cent. and 3 per cent. The change from black to grey is apparently due more to a physical change than to any appreciable difference in the percentage of volatile matter. Several hundred tons of this coke have gone through the blast furnaces in Scotland.

The oil yields range from a very few gallons per ton, with strongly coking coals of low volatile content, to 30 or 40 gallons per ton with coals of a canneloid nature. The average yield for bituminous coals lies between 14 and 20 gallons. The oil yields are the highest possible from the kind of coal used, as less decomposition of the oils takes place than in any plant hitherto known. Because of this a new series of commercial products are obtainable from the oils. The crude oil is usually a thick brown liquid, with a setting point between 20 deg. C. and 30 deg. C. These oils are readily separable without distillation into four distinct portions:—(1) An asphaltic portion, somewhat similar to bitumen or asphalt; (2) a more resinous portion, consisting largely of phenols of high boiling-point, the value of which ranges between 3*s.* 6*d.* and 4*s.* per gallon; (3) a third portion consisting of the known phenols, from carbolic to the xylenols, which at present have a value between 1*s.* 6*d.* and 2*s.* per gallon; (the phenolic portions have been used for the manufacture of resins and lacquers. The total percentage of phenols obtainable is from four to ten times greater than from high-temperature tars); (4) a neutral oil rich in paraffin wax. The lighter portions of this can be used for lubrication for fuel for Diesel and other motors, the heavier for the recovery of paraffin wax, or the whole of the neutral oil can be converted into a lubricating grease which has been used satisfactorily for motor axles, Stauffer cups, for ball bearings running at 1,700 revolutions per minute, and for shaft lubrication, and yet is so cheap as to make its use possible on colliery tubs. The oil contains practically no petrol. The simplest treatment, however, is to make two products only, viz., refined tar and creosote oil. Present values of refined tar and creosote run between 7*d.* and 10*d.* per gallon.

The ammoniacal liquors obtained differ from ordinary gas work and coke oven liquor in being free from ferrocyanides and sulphocyanides. Instead, they contain polyhydric phenols, one of which gives a blue colour with iron, and another gives a quinone oxime, somewhat similar to resorcinol green. The green used as a pigment gives green shades, and it is the first dye to be taken direct from ammoniacal liquors. The ammoniacal liquors also give a black product, which can be used as a drop black, and a brown pigment, which is in demand as a paper stain. The ammonia can be obtained as white sulphate, by ordinary gas-works methods. The yields are from 16 lb. to 80 lb., according to the nitrogen in the coal used, and whether the plant is run for coke or for complete gasification.

For the burning of bricks and clay goods generally gas must be very cheap to make its use at all practical. Hence town gas (ordinary coal gas) and water gas cannot be seriously considered for the purpose. As regards producer gas, the author estimates that for ordinary producer gas and Maclaurin producer gas alike the cost on a large scale, reckoning coal at 20*s.* per ton, would be about 27*s.* for the gas from one ton of coal.

The cost per therm (= 100,000 B.T.U.) of gas produced by different processes when working on a large scale may be taken as for:—

Distilling coal in closed retorts	6*d.* to 3*d.*
Gasifying coal in water-gas plant	4*d.* to 2*d.*
Gasifying coal in non-recovery producers	2¼*d.* to 1½*d.*
Gasifying coal in Maclaurin producers....	1½*d.* to ¾*d.*
Gasifying in coal according to quality	2*d.* to ½*d.*

The comparatively lower cost of producer gas is due to the relatively low capital cost. In recovery producers the relatively high capital costs and high steam consumption is compensated by the return from the ammonia and tar, and, therefore, under certain conditions of the market, recovery producers may be able to produce gas for less than 1½*d.* per therm. In the Maclaurin producers the interest, repairs and depreciation charges and working charges (including steam) are very low, and these are recovered in the returns obtained for the oil and ammonia, when working for complete gasification, and from the coke also when working for this.

The cost of producing gas will vary with the market value of the by-products. The Maclaurin plant can be run under so many conditions that some adjustment to meet fluctuating market conditions is possible. The author gives figures showing that the net cost of gas can come well under 1*d.* per therm, after providing 25 per cent. on the capital cost for interest, repairs and depreciation. It has been calculated that, by dealing with the complete output of a colliery in a Maclaurin plant, the gas can be made at a cost of about ¾*d.* per therm.

The capital cost of a battery of two units capable of carbonising 40 tons of coal per day works out at about 10*s.* per ton of coal carbonised per annum. On a ten-unit battery capable of carbonising 200 tons per day the capital cost comes down to about 8*s.* per ton at present prices. The working costs per ton decrease fairly rapidly from a two-unit to a six-unit battery, but for any further increase the savings are not very marked.

The remainder of the paper discusses in some detail the suitability of the gas for use in firing ceramic products, and also for supplying power in potteries. The gas from a Maclaurin producer working for coke is specially recommended because of the exceptional percentage (13) of methane (CH_4) in such gas, the methane giving a flame of considerable length.

Mr. L. M. Wilson, M.Sc., next read a paper on "The Effect of Salty Coal upon Refractory Materials." Reference in this is made to Thompson's investigations on the action of sodium chloride (common salt) on silica and other refractory materials. The author's work was confined to studying the effects upon refractory materials of ammonium chloride, which is found in coke-oven gas from salty coal. As a result of preliminary experiments, it was found that pieces of silica brick heated in contact with ammonium chloride lost part of the iron oxide and titanium oxide, the action taking place uniformly through the material, and that pieces of fireclay brick under similar treatment lost some of the iron oxide, but in this case the action did not proceed uniformly throughout, the removal taking place from the outer portions. It was also found impossible to bleach completely a piece of the same firebricks until a temperature of 1,100 deg. C. had been maintained for 24 hours, practically all the iron being then removed.

Experiments with larger quantities of fireclay brick were made at temperatures ranging from 1,265 deg. C. down to 830 deg. C. for 24 hours. The results showed that by increasing the temperatures the proportion of alumina removed from the brick was increased. It also became manifest that there is a critical temperature at about 900 deg. C., where the chemical properties of burned fireclay seem to undergo a change, quite apart from the critical temperatures at which the physical properties of either raw or fired materials are known to alter. Below 900 deg. C. very little alumina was removed, but above 900 deg. C. the proportion of alumina removed increased rapidly. Free silica (in the form of a silica boat) helped in the removal of alumina from fireclay, affording another instance of interaction of solids at temperatures below the fusing point of either of them.

The experimental evidence demonstrated the superiority of high-grade silica over fireclay for the lining of coke ovens as regards resistance to salty coal. It is also concluded that, at temperatures from 700 deg. C. to 1,200 deg. C., or higher, ammonium chloride removes iron oxide and alumina from fireclay or from silica bricks.

The last paper was by Mr. Walter Smith on "Carbonisation of Clays." In this it was shown that by saturating clay, at a certain stage of heating, with hydrocarbon gases or volatile hydrocarbons under pressure, the gases undergo dissociation and deposit very finely-divided carbon on the particles of the clay. This takes place during the "biscuit" period of the clay, when it has maximum porosity, and before the characteristic firing contraction of the clay has fairly set in. The biscuit clay thus carbonised is black, however finely divided it may be, and when, during subsequent heating in the final stages of firing, the contraction of the clay takes place, great pressure is exerted on the enclosed particles of carbon and a dense, hard, composite body is formed. The product by firing in a strongly oxidising flame is capable of being converted into a microscopically porous structure owing to burning away of the carbon, the refractory properties being highly increased. If the clay be properly carbonised the impurities will be considerably reduced.

For the black carbonised clay the term "carbonite" is suggested for industrial purposes. This hard and tough material is best adapted for abrasives, for mixing with cement, for roadmaking, etc. It is also very refractory to heat in the absence of air and very resistant to acids, as well as impervious to weather or atmospheric action.

The white carbonised clay (from which the carbon has been burned out) might be termed "carbo-calcined clay." It owes its refractory properties to the artificially-produced porosity, and in general it refuses to

melt at anything near the same temperature as the original material.

The durability of the carbonised brick in the industrial furnace has been proved to be much greater than that of bricks produced from the natural clay.

The binding of carbonised clay is accomplished by pressure, just as with magnesite. Artificial binders should be used sparingly, and in the case of carbo-calcined materials the binder should preferably have the same composition as the original clay.

Carbonisation increases the normal formation of sillimanite in aluminium silicates, as indicated in micro-photographs of Ayrshire bauxite clay and some other clays. The author states that, by special treatment of certain clays, the production of a brick, retort, and crucible consisting mostly of sillimanite has been accomplished on a small scale. Bricks made from carbonised clays may broadly be defined as possessing refractoriness and hardness, and as exhibiting little or no contraction or expansion.

NOTES ON NEW BOOKS.

THAT a book should have passed into its third edition is a sufficient testimony to its popularity, and judged by this test "*Popular Fallacies Explained and Corrected*" has met with a highly appreciative public. The author is Mr. A. S. Ackermann, B.Sc., whilst Sir R. A. Gregory has contributed an introductory note. The book is published by the Old Westminster Press at 12*s.* 6*d.*, which is a low price considering that the volume contains nearly 1,000 pages. The field covered is very wide, ranging from domestic matters up to questions in biology and astronomy. The section dealing with engineering and science covers 146 pages. There is an old saw to the effect that "who drives fat cattle should himself be fat," and it is accordingly-perhaps only in consonance with the eternal fitness of things that the author supports one of the worst "howlers" in the book. Accepting a "proof" by Professor D. A. Low, he asserts that a column fixed at one end is only one-fourth as strong as a column of equal length hinged at both ends. The blunder has arisen from a misunderstanding of Euler's theory, and illustrates once again the value of the precept which a professor of engineering of former days used to impress on his students, viz., that if a calculation leads to a result at conflict with common sense, the calculation should be scrapped. In arriving at the preposterous statement quoted it has been assumed that a column fixed at one end can be considered as the half of a column hinged at both ends, and so, of course, it can. It has not been realised, however, that Euler's theorem gives more than one curve of equilibrium for a two-hinged column, and that a column fixed at one end corresponds to the three-lobed deflection curve and not to the single lobed curve. The true comparative figures are given in Castigliano's "Théorie de l'équilibre des systèmes élastiques." For a column hinged at both ends the crippling load is $P = \pi^2 \frac{E I}{l^2}$, whilst for a column fixed at one end the crippling load is $\frac{9}{4} \pi^2 \frac{E I}{l^2}$ or more than twice as great, instead of only one quarter as much as stated in the text. It is distinctly unfortunate that such a very serious error should have marred a painstaking piece of work.

As a means of generating electricity for small users the petrol-driven engine and dynamo set has become very popular. This has prompted the preparation of a book on "*Small Electric Lighting Sets*," by Mr. C. F. Caunter, which was published recently at a price of 3*s.* 6*d.* net by Messrs. James Munro and Co., Limited, of Washington-street, Glasgow. As an attempt to describe the salient features of the engines and the cycles of operations taking place in their cylinders, the work has much in common with the cheap books on motor cycles, motor cars and motor boats. The generator is also dealt with on a similar scale, but when automatic operation of the plant has to be referred to, the author points to the limited size of his volume as an excuse for the meagreness of the treatment. This is much to be regretted, as the subject is perhaps the only one on which the user may be expected to know little or nothing, and may be the one on which he most desires information. Many different makers' designs are referred to, but there are some with distinctive features and in common and successful use, which the author has evidently not thought of sufficient importance to include. There is a fair amount of information on setting-up and running the plants, which will prove useful to the reader for whom the book is intended. The looseness of many statements made by the author is to be deprecated. As examples, such sentences as "The gas mantle of then (1884) is much the same as is sold in the shops now, and it is very doubtful whether any real advance will be made on this method, in view of the serious rivalry of electricity," and "In 1894, another form of gas lighting was invented in the form of calcium carbide or acetylene," may be cited.

In a paper just published at Prague by "Masarykova Akademie Prace," Professor Z. Bazant discusses the "*Influence du système de triangulation sur les efforts secondaires.*" The paper opens with the following remark, which we imagine the author would, have considerable difficulty in substantiating, "La securité et la durée d'une construction dépend non seulement des efforts primaires que l'on calcule pour les systèmes de barres, en supposant des articulations dans tous les noeuds, mais aussi des efforts secondaires qui sont la conséquence des assemblages rigides ordinairement employés dans les constructions métalliques." This view is no doubt widespread in many places where they teach, but receives little or no support from practical experience. Hundreds, probably thousands, of bridges have been built in which calculation indicates the existence of high secondary stresses, but we know of no catastrophe due to these, although as the result of his calculation Professor Bazant finds that in certain cases the secondary stresses may exceed the primary. The author determines the relative value of the secondary stresses corresponding to different methods of triangulation and pronounces himself strongly in favour of the "K" type which was adopted for the new Quebec Bridge. This, he states, gives rise to the smallest secondary stresses and yields a "smooth" deflection curve. This latter conclusion was, we believe, reached by the engineers to the Quebec Bridge. Although, as indicated, we do not believe in the practical importance of secondary stresses, unless in cases of actual stress reversal, engineers ought certainly to be acquainted with the methods by which such stresses can be computed, and Professor Bazant's paper will accordingly prove of interest to many.

Lecturers on machine design and students generally will find useful two books published by the McGraw-Hill Publishing Company, Limited, London. The one is entitled "*Problems in Machine Design*," and has as its author Professor O. A. Leutwiler, of the University of Illinois. The price of the issue is 7*s.* 6*d.* net. In this treatise Professor Leutwiler has collected together an instructive series of problems, such as may and do arise in actual practice. He shows clearly how, what is essentially the same problem, may crop up in different forms. Thus starting with a symmetrical link, he shows how the stresses are increased if for any reason it may be necessary to use a bent link, and is thus led to the stresses in clamps, which it may be added resemble, from the point of view of the stresses developed, many machine frames, though these are not considered till a later chapter. The problems are progressive in difficulty, and in the final chapters the reader is confronted with the task of determining the proportions of the component parts of certain complete machines. The second work, entitled the "*Design of Machine Elements*," is published at 12*s.* 6*d.* net. It has been prepared by Professor J. A. Mease and Professor G. T. Nordenholt, of Lehigh University. It opens with a discussion of the properties of materials and of elementary theoretical mechanics. Following this the design of machine elements is discussed in detail; commencing as usual with the problems presented by different forms of fastenings, such as bolts, rivets and gears. Shafting and power transmission are next considered, and this leads to chapters on various forms of gearing. Bearings of different types are next dealt with, and there is a useful chapter on springs.

Text books on electrical engineering, as a rule, are inclined to devote the greater part of the space at their disposal to generating machinery, dealing very inadequately with the apparatus necessary for the control of the electrical energy after it has been produced. The problems involved in the design of controlling apparatus, however, are certainly of no less importance to the electrical engineer than are those connected with generating plant, since the former is, if anything, of greater variety and complexity than the latter. Students of electrical engineering therefore will doubtless welcome the publication of a little book which forms one of the Oxford Technical Publications and has been written by Mr. A. G. Collis. It is entitled "*Practical Control of Electrical Energy*," and its object is to give descriptive technical data of the design of apparatus and plant in everyday use for this purpose. After explaining the units and terms employed, the author deals with measuring instruments for direct and alternating currents, synchronisers, leakage indicators, automatic regulators, protective gear, switch gear and switchboards, motor starters, &c., explaining the principles involved and giving examples of various types. The explanatory matter appears to be clear, concise and accurate in all cases, and as it is accompanied by very numerous illustrations, it will be readily followed by the average student. The mathematical knowledge of the reader will certainly not be taxed, since the author has intentionally avoided the use of any but the simplest expressions. The book should therefore appeal to the practical man in charge of plant, as well as to the student. It is published by Messrs. Henry Frowde and Hodder and Stoughton, 1 and 2, Bedford-street, Strand, London, W.C. 2, and its price is 10*s.* 6*d.* net.

A comprehensive little treatise on the "*Elements of Graphic Statics*" has just been issued by the McGraw-Hill Publishing Company, Limited, London, having been prepared by Professor C. W. Hudson and Professor E. J. Squire, of the Polytechnic Institute, Brooklyn. In some 90 pages the authors cover pretty completely the whole field so far as statically determinate structures are concerned. Possibly some students may feel that the work of compression has been carried too far, as the reader cannot safely skip a line. In addition to dealing with really statically determinate structures the authors include a section on arches. The difficulty arising from the real indeterminateness of the stresses in such structures is avoided by adopting Rankine's rule that a masonry arch is safe if a line of resistance can be drawn "within the middle third." A very neat way of determining whether this is possible was described by Professor Fuller many years ago, but the authors are apparently unacquainted with it, and their own methods are more tentative.

THE LATE DR. J. A. HARKER.

THE name of Dr. Harker, F.R.S., who, we are sorry to record, died at Highgate on October 10, has often been mentioned in our columns, especially in connection with his work at the National Physical Laboratory and later at the Ministry of Munitions.

John Allen Harker was born at Alston, Cumberland, on January 22, 1870, and was thus only in his 54th year at the time of his death. His father was the Rev. J. Harker, a Congregational minister. Educated at Stockport Grammar School, he studied at Manchester University, where he was elected Dalton scholar in chemistry in 1891, and a year later Berkeley scholar in physics, and took his M.Sc.; he then proceeded to Tübingen. At the National Physical Laboratory he was one of Sir Richard Glazebrook's original assistants, to whose devotions so much of the success of that Institution is due. In charge of the thermometry department, of which he became chief, he was notably active in researches on electric furnaces, and on pyrometry and the Féry and other pyrometers; the time he had spent in Sèvres in collaboration with Chappuis (on gas thermometry) and also Mousan (on furnaces) was very useful to him in these investigations. Never of strong health, he went to Eskdalemuir as temporary superintendent of the observatory in 1913. When the war broke out in 1913 he was lent to the Inventions Department of the Ministry of Munitions and became director of the research laboratories and organiser of the Nitrogen Products Committee of that department. In that connection he paid visits to the United States and Canada in 1918, and also to France and Scandinavia; on the former occasion his ship was torpedoed off the North Coast of Ireland. After the war he remained connected with the department of Scientific and Industrial Research; he did not return to Teddington, but started as a consulting physicist in Westminster.

His scientific papers were contributed mostly to the Royal Society and to the *Philosophical Magazine*. He was a Fellow of the Royal Society and at various periods a member of the Councils of the Physical and Faraday Societies, and of the British Association Committee on Gas Engines. In 1912 he represented the British Government at the International Petroleum Congress in Vienna, at which his own researches on the flash testing of oils enabled him to make valuable contributions to the discussions. Dr. Harker leaves two sons and three daughters; his wife, the daughter of the late Thomas Richardson, J.P., also comes from Alston. The funeral will take place at Golder's Green to-morrow.

THE KRUPP WORKS AND MEXICO.—According to *The Iron Age*, New York, while denials have been made by officials of the Monterey Iron and Steel Company, reports from other sources persist to the effect that the Krupp Works are negotiating for the purchase of the Mexican company's plant, particularly for the purpose of obtaining control of its ore mountain, Cerro de Hierro, in the State of Durango, several hundred miles from the company's steel works. It is claimed that the negotiations are being conducted by a Mr. Hehny, representing the Krupp Works, and now in Mexico. It is further stated that Mr. Hehny has been visiting all the stockholders of the Monterey Company in an effort to buy the stock at par. The corporation has not been paying dividends. The mountain in question is said to contain very large quantities of ore, and this would be of great value to the Krupp concern, which would either convert it into pig-iron or ingots, and ship the manufactured product to their plant in Germany for finishing.

THE PNEUMERCATOR DISTANT-READING BOILER WATER-GAUGE.

CONSTRUCTED BY MESSRS. KELVIN, BOTTOMLEY AND BAIRD, LIMITED, ENGINEERS, GLASGOW.

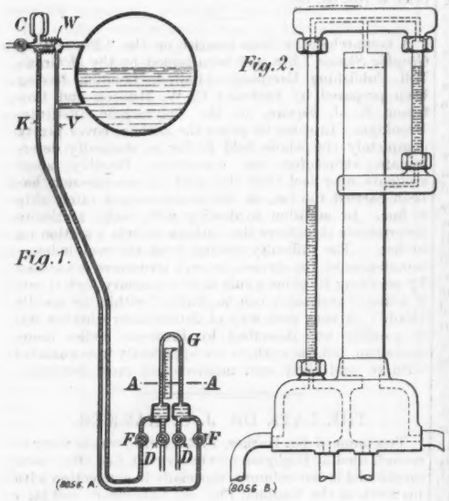


Fig. 1.

Fig. 2.

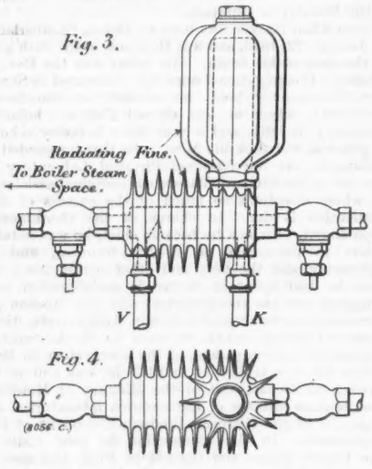


Fig. 3.

Fig. 4.

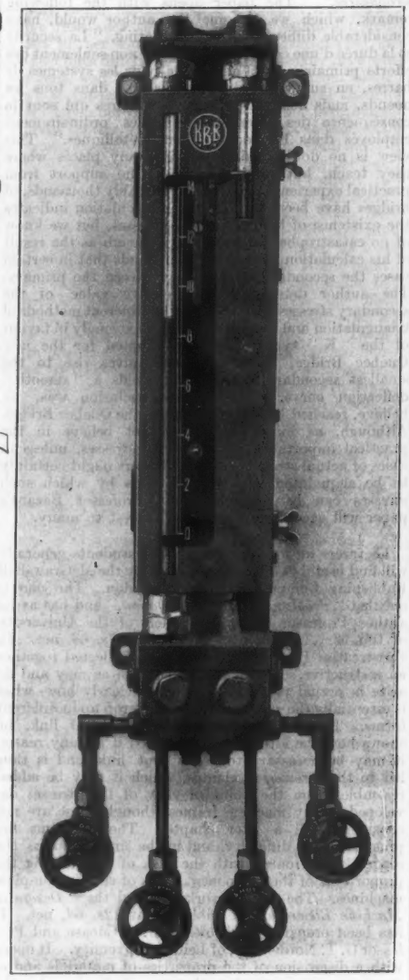


Fig. 5.

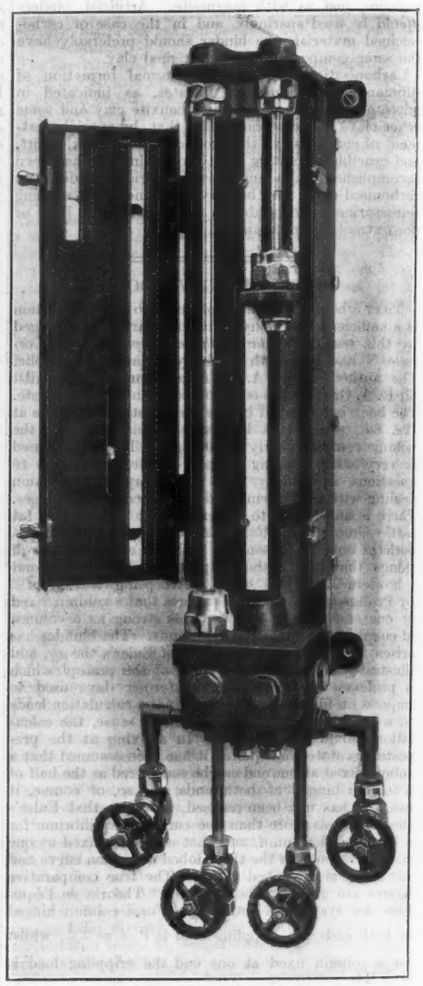


Fig. 6.

The most difficult instruments to read in an ordinary power station are undoubtedly the water-gauges on the boilers. They are, at the same time probably the most important indicators for the operator to watch, for inattention to their evidence may result in disaster of the most extensive kind. Much of the difficulty of reading the water-gauges in modern stations is due to the great height above floor level at which they are placed, and conditions are often made worse by the presence of a gangway along the boiler fronts just below the drums. A very large number of devices have been brought out with the object of rendering the water level in the gauge clear and unmistakable, but all inventors, heretofore, have taken it for granted that the gauges must necessarily be situated at about the centre line of the steam drums, which may be 20 ft. or more above the floor level in a modern boiler-house. This condition is really at the root of the difficulty of visibility, but that such a position is not essential is shown by the ingenious arrangement adopted by Messrs. Kelvin, Bottomley and Baird, Limited, of 18, Cambridge-street, Glasgow, who have devised a form of water gauge which can be placed in practically any position where it is most convenient for observation.

The gauge in question, known as the "Pneumercator" water gauge is essentially a distant reading water gauge. It may be brought down, therefore, to a level with the boiler attendants' eyes, and placed adjacent to the pressure gauge, steam flow meter and other instruments of the boiler-house, so that it shares with them ready visibility and ease of reading. It works moreover with cold water, which is a distinct advantage over water gauges of the ordinary type, in which the glasses are subject to the temperature of the steam. The principle of operation of the pneumercator gauges is extremely simple, and will be understood by reference to Fig. 1, above, where the gauge is shown diagrammatically at G as an inverted U-tube. The steam space of the boiler is connected to a small chamber C provided with radiating fins, and having inside it a weir W. This chamber is shown to a larger scale in Figs. 3 and 4. Two small pipes K and V connect the lower side of the chamber C to the two limbs of the gauge G, and the pipe V is also connected to the water space of the boiler, as shown.

By operating the stop valves F and the drain valves D, the gauge system is charged with water when the apparatus is started up, a cushion of air being trapped in the upper portion of the inverted U tube, which forms the gauge G. The radiation of heat from the chamber C causes steam to condense within it. The resulting water fills the pipe K and the lower part of the chamber, up to the level of the top of the weir. Any surplus condensate overflows the weir and flows back to the water space of the boiler through the pipe V. It is obvious therefore that when the gauge is in operation the pipe K is filled with water at a constant head, while the water in the pipe V stands at the same level as the water in the boiler. As there is no circulation in the pipes the water in them is cold. The water in both pipes is subjected to the same boiler pressure, and similarly, of course, the air cushion acts with equal pressure on both pipes. Hence the water in the two limbs of the U tube must stand at a difference in level, which exactly represents the difference in level between the water in the pipes K and V. If the chamber C be so placed that the top of the weir is level with the top of an ordinary gauge glass, then the difference in the levels in the U-tube shows how far the water level in the boiler is from the top of the glass. Thus the water level may be ascertained from the indications of a pneumercator gauge situated quite at a distance from the boiler-drum with which it is connected and at any lower level that may be desired.

Placed between the two limbs of the gauge is a scale of inches equal in length to the ordinary boiler gauge glass. If the top of this scale is placed level with the right-hand water column, the water level in the boiler can be read from the left-hand column exactly as in the case of an ordinary gauge glass. It will be noted that any change in the boiler pressure will affect the volume of the air imprisoned in the bend of the U-tube, and consequently the water level in both tubes will be altered, their relative positions of course remaining the same. To compensate for such changes in pressure the scale of the simple type of gauge G shown in Fig. 1 requires to be moved up and down, in order that its upper end shall always coincide with the level of water in the right-hand limb when a reading is taken. This would, of course, be troublesome in practice, so, to avoid the difficulty Messrs. Kelvin, Bottomley and Baird, Limited, make the right-hand limb of the gauge of much greater sectional area than the other, the actual arrangement adopted being shown in Fig. 2. In consequence of this, and of the provision for entrapping exactly the right quantity of air, normal changes in pressure when the boiler is working have no visible effect on the water level in the right-hand limb of the gauge, so that the scale does not require any adjustment under working conditions.

In carrying out this enlargement of the right-hand limb, glass tubes of large diameter are avoided, the limb being made of a stout metal tube. The water level in this limb is read by means of a short sight glass connected to the limb as shown in Fig. 2. The left-hand limb is an ordinary gauge glass, both glasses being of standard size. The effect of enlarging the right-hand

SINGLE-RUNNER OVERHUNG PELTON TURBINES.

CONSTRUCTED BY THE PELTON WATER WHEEL COMPANY, ENGINEERS, SAN FRANCISCO.

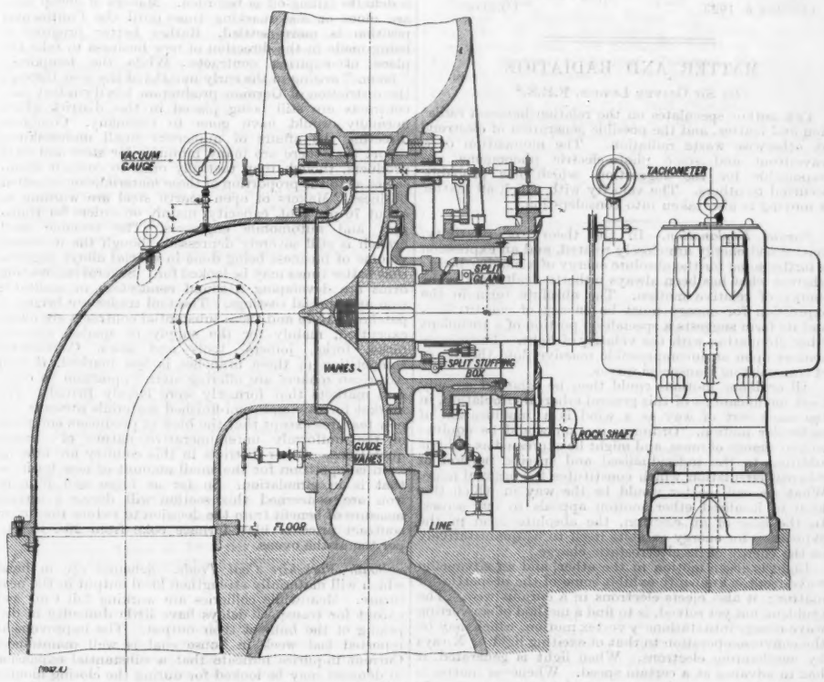


FIG. 1.

limb is that a relatively large percentage increase or decrease in the volume of the entrapped air involves only a small movement of the water in the enlarged tube, and consequently also in the gauge glasses.

Figs. 5 and 6 show a complete pneumercator gauge as installed in the Dalmarnock Power Station of the Glasgow Corporation. The gauge scale is external, being mounted on the front of a hinged door fitted with non-shatterable glass windows through which the gauge glasses can be seen. The pipes connecting the instrument to the boiler drum are of heavy gauge brass, about $\frac{3}{8}$ in. diameter, and are run together so that temperature differences are avoided. In service the gauge shows all fluctuations of water level in the boiler, and is in fact a replica at a distance of the ordinary water gauge with the very important difference that the pneumercator gauge works with cold water. It is generally agreed that the comparatively short and erratic life of boiler gauge glasses is due to the combined effect of pressure and temperature upon them. Gauge glasses can be got which will stand a cold test of 2,000 lb. per square inch, but they certainly could not be worked at this pressure and at the corresponding temperature of saturated steam. The high pressures now in use and in contemplation make the question of gauge glasses a serious one, and the fact that the pneumercator gauge glasses are always cold and can be placed in any position most convenient for visibility, regardless of the height of the boiler, is sufficient to recommend the apparatus to all engineers in charge of large boilers. The gauge at Dalmarnock has been in service for six months, during which period no tendency for the leakage or absorption of the air has manifested itself.

SINGLE-RUNNER OVERHUNG PELTON TURBINES AT FAGUNDES, BRAZIL.

THE City of Bahia, Brazil, and its vicinity, have been supplied with electricity by the Cia Brazileira Energia Electrica, from an hydroelectric plant on the Paraguasu River, consisting of three 5,200-h.p. Pelton twin runner turbines operating under an effective head of 110 ft. A steadily increasing demand has made it necessary to construct another plant, and a suitable site for this was found on the Fagundes River, where it was possible to secure a static head of 415 ft., or an effective head of from 365 ft. to 374 ft.

The pipe line for this project consists of 5,128 ft. of 66-in. lap-welded steel pipe. Of this the upper 3,032 ft. are $\frac{7}{16}$ in. thick and the remainder $\frac{3}{8}$ in. or more thick. This line ends in a distributor arranged at right angles to the penstocks leading down to the station. The distributor is 95 ft. below the normal water level of the forebay. The two penstocks are 725 ft. in length and run parallel down the slope, connecting directly to the inlet gate-valves at the turbines. The penstocks are of plate, $\frac{7}{16}$ in. thick for the upper 100 ft., and $\frac{3}{8}$ in. thick and more below. At the distribution level is a main surge pipe 279 ft. long and 84 in. in diameter, of steel plate riveted. The top of this is 75 ft. above normal water level in the forebay. An auxiliary surge pipe is provided at a point 3,361 ft. from the inlet of the 66-in. pipe line. This is 201 ft. long, of 66-in. diameter, and with its lower end 56 ft. below, and its upper 75 ft. above, the normal level in the forebay.

The two hydraulic units are Pelton single-runner overhung reaction turbines, each developing 4,000 h.p. at full load and similar in design except that one is right-handed and the other left. These machines are illustrated in Fig. 1 annexed, and Figs. 2, 3 and 4, on page 464, the latter showing the governor. The generator is mounted between the two bearings, as will be clear from Fig. 2, which shows one unit and the vane or gate-operating mechanism. This design of turbine has been developed by the Pelton Water Wheel Company, of San Francisco, particularly in connection with the larger sizes of spiral case single discharge machines. One of the important features of the construction is that the interior of the turbine is very easily accessible, in the event of inspection or repairs being necessary. Removal of the discharge elbow is all that is necessary, the generator, shaft and bearings being left undisturbed. The whole of the regulating mechanism can also be left untouched since it is independent and clear of the turbine casing. It is also possible to remove the ring casing cover on the outboard or discharge side of the turbine, and to take out all the vanes or wicket-gates without disturbing the gate-regulating ring or the connections to the governor rocker shaft.

The main bearing is of the pedestal type with oil ring lubrication supplied from a reservoir in the base. The runner is of bronze cast in one piece, and is balanced at all loads, though to guard against contingencies setting up an hydraulically unbalanced thrust, a Kingsbury thrust bearing is embodied in the outboard bearing, which, otherwise is similar to the main bearing. The relief valve is of the needle type, and has a capacity corresponding to full load conditions on the turbine. It is controlled by the governor, and opens directly and instantaneously with the closing of the guide vanes, subsequent closing being slow, to avoid water hammer. The rate of closing is adjustable, while the amount of closure of the guide vanes which causes the relief valve to operate is also capable of adjustment.

The governor is of the Pelton vertical spindle belt-driven servo-motor type, the governor controlling a distributing valve which admits oil pressure to one side or the other of a piston coupled to the vane-operating gear. Oil pressure is maintained by means of a small pump, and the supply is accommodated in the vertical cylinder shown adjacent to the governor in Fig. 4. The pressure pump operates continuously, but when the oil in the pressure tank reaches a predetermined level an unloader valve opens and remains open until the oil falls below that level. A full stroke of the governor can be made in 2 seconds. The governors are capable of limiting the speed rise under full-load rejection to 24 per cent., and proportionately less for smaller rejections.

The generators are 3,000-k.v.a., 2,300-volt, three-phase 60-cycle machines, by the General Electric Company. The turbines are designed for maximum efficiency at three-quarter full load, the guarantees being as follows: 4,000-h.p. output, efficiency of 85 per cent.; 3,000 h.p., efficiency of 88 per cent.; 2,000 h.p. output, efficiency of 82 per cent. The turbines and accessory hydraulic equipment were built at the Pelton Water Wheel Company's San Francisco works and shipped from there direct to Brazil.

"A METHOD OF IMPROVING THE WAVE SHAPE OF ALTERNATORS."

TO THE EDITOR OF ENGINEERING.

SIR,—Since the meeting of Section G of the British Association, I have looked through the journal mentioned in the discussion, the Archiv fur Electrotechnik, to see whether I could find an account of an arrangement similar to that which I described, but have not succeeded in my search.

Mr. Jack, also, referred to the fact that a device similar to the one I described had been used by the British Thomson-Houston Company, but of this, also, I have found no account anywhere. The use of "resonant shunts" on telephone circuits to prevent interference by induction is mentioned in a paper in the Proceedings of the American Institute of Electrical Engineers, but this, of course, is a different device from the one which I described, in which ripples are got rid of *at the source* by using circuits of zero reactance across the supply and a limiting reactance in the main circuit (or in the case of three-phase generators, in the neutral circuit), to reduce the ripple frequency currents to smaller dimensions. The same arrangement as that described in my paper can be applied to direct-current circuits to get rid of ripples. Although the old saying that "there is nothing new under the sun" *may* be true in this case, up to the present I have not found any reference to a device of this nature in previous literature.

Yours very truly,

E. W. MARCHANT.

Laboratories of Applied Electricity, The University, Liverpool, October 6, 1923.

LOCOMOTIVE COPPER STAYS.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with considerable interest the letters of Alfred Herbert, Limited, and H. N. Gresley regarding the design of locomotive fire-box stays, and perhaps I can throw some light on the subject from a running-shed point of view. There is no doubt that many stays are incorrectly fitted, and that the threads of the stays do not engage accurately with the threads in the hole. The method of fitting stays as suggested by Alfred Herbert, Limited, would be an improvement in this direction but would weaken the stays. Tensile tests made some time ago on copper stays with holes drilled in one end and screwed to receive a screw gave the following results:—

Description of Test.	Broke at Actual. Tons.
1. 1-in. copper stay riveted at both ends	8·5
2. 1-in. copper stay with $\frac{1}{4}$-in. hole drilled and threaded in one end, $\frac{3}{4}$-in. deep, and screw inserted ...	6·92
3. $1\frac{1}{16}$-in. copper stay riveted both ends	10·2
4. $1\frac{1}{16}$-in. copper stay drilled with $\frac{1}{4}$-in. hole and threaded in one end, $\frac{3}{4}$ in. deep, and screw inserted ...	7·82
5. $1\frac{1}{4}$-in. copper stay riveted both ends	14·5
6. $1\frac{1}{4}$-in. copper stay with $\frac{1}{4}$-in. hole, drilled and threaded in one end, $\frac{3}{4}$ in. deep, and screw inserted ...	11·43

Considering these results it would appear to be inadvisable to drill holes in stays, but as broken stays are rare in modern locomotive boilers and as they work at a factor of safety of 7 or 8, there would be no danger in drilling $\frac{3}{8}$ in. or $\frac{1}{2}$ in. tapered holes in stays $1\frac{1}{16}$ in. diam. and filling with a plug. The tendency of the stay to close and draw out of the hole should the plug drop out is negligible, as the threads would be a good fit and the metal surrounding the hole a good thickness.

Regarding the cause of small stay heads my experience is that wasting is due to erosion by the solids carried with the flame and corrosion from slight leakages. The

scouring action of the solids in the gases is necessary to disperse the gas film on the plates and of course acts more fiercely on anything projecting beyond the surface of the plate. Stay heads are thus rapidly worn, but once they are small the wear is very slow. Corrosion of stay heads takes a peculiar form, and is more noticeable in the top rows and near the flanges. Portions of stay and plate will be found corroded on one side of the stay only. Reading from the fire-door end the stays will be corroded on that side nearest the fire-door until half-way to the tube-plate when corrosion takes place on the opposite side of the stays. On each side of the fire-door the stays are usually found to be corroded evenly all round.

I am of opinion that stay heads are made too big and excessive hammering to form a large head is detrimental to the threads of the stay. At the same time I do not think it is a practical suggestion to make stays flush with the plate as there would be no means of tightening the taper plugs should leakage occur. Also a head forms a means of arresting corrosion by allowing metal to be drawn into the hollow made by corrosion. It was in my apprentice days when I first saw stays with small heads drilled and drifted to obtain a better mileage before shopping, and now the subject has been revived I should be glad to hear of someone giving the suggested method a trial.

Yours sincerely,
A. Wrench.

8, Union-street, Crewe, October 8, 1923.

To the Editor of Engineering.

Sir,—In reply to the queries raised by Messrs. Herbert in your issue of the 5th inst. :—

(1) The burning of the heads is practically entirely due to erosion. This is borne out by the fact that the majority of burnt heads occurs in the lower part of the fire-box, where attrition due to the action of the flames and particles of fuel is, of course, greatest. Stays in the upper rows, although subjected to the maximum bending stress, give very little trouble of any description, and have the longest life, usually serving from one shop repair to another without any attention whatsoever.

Incidentally, one occasionally encounters stay heads which have been damaged, not by burning, but by careless manipulation of pricker and slice on the part of the fireman.

(2) A perfect metal-to-metal contact between stay and plate would probably conduce to a more rapid heat transference from metal to water—but is perfection, in the true sense of the word, obtainable, and would such a joint retain its state of perfection for a longer period than the existing types of joint under the rigorous conditions obtaining, and severe fluctuations of stress occurring in a locomotive fire-box ?

Again, I am open to correction, but my interpretation of the laws of heat transference leads me to the conclusion that by far the greater quantity of heat transmitted by the stay travels, not as Messrs. Herbert would seem to suggest, from the threaded portion *via* the fire-box side sheet to the water, but directly to the water from the large area of stay exposed in the water space. I do not agree that "stays as used at present allow the ingress of scale"; if extensive leakage has occurred, traces of scale may occasionally be seen at the roots of the thread. Ordinarily, however, the thread is found to be as clean on withdrawal as when originally placed in the fire-box.

Whatever type of stay is used, scale will always form on the shank in the water-space, and cannot be removed by the washer-out on account of its manifest inaccessibility. I incline to the opinion that after a considerable mileage, a certain proportion of the scale dislodged from the crown sheet by the rods in washing out is not washed away, but is trapped by, and finally adheres to the stays. In any case, this formation of scale considerably lowers the efficiency of conduction, and the consequent concentration of heat in the stay is a known cause of burning-off.

(3) Boiler corrosion takes place internally, and therefore does not directly affect the head of the stay.

(4) It should be remembered that the function of the stay-head is not only to make the joint tight, but also to protect the threads from the action of the flames, and in the case of a flush-headed stay I consider this action would very quickly commence to attack the stay at the lead-off of the thread, however fine the pitch might be.

I fail to see why the principle of fixing boiler tubes should be cited as a parallel case. In the first instance the conditions are so widely different; assuming an efficient brick-arch, the tubes are not in direct contact with the flames, nor subjected to the action of fuel particles to such a degree as are the stays. Again, owing to the large area taken up by the tubes, the resultant fluid pressure on the tube plate is small, and the staying action required of the tubes is also very small in consequence. Further, the question of the temperature ranges and stresses is obviously very much less acute. Finally, tubes at the fire-box end cannot be considered as flush-jointed; apart from being expanded, they are always beaded over, and on most railways, ferruled in addition.

It may be of interest to know that, many years ago, the late Mr. Park, locomotive superintendent of the North London Railway, introduced a form of threaded stay in which all riveting was obviated. A hole was drilled centrally at each end of the stay, and the final tightening of the stay against the plate was effected by means of a conical drift. I believe the design was not perpetuated, however, as the transverse resistance was too great to allow of sufficient yield to the expansion of the fire-box.

In conclusion, I should like to state that the standard practice on the railway with which I am connected is to use a solid copper stay, 1 in. in diameter, having 12 threads per inch, and riveted over at each end. This type of stay has given very satisfactory results over a period of several years, and although using indifferent water, we have had very little trouble as regards the burning-off of heads.

Yours faithfully,
"Gerloco."

October 8, 1923.

MATTER AND RADIATION.

By Sir Oliver Lodge, F.R.S.*

The author speculates on the relation between radiation and matter, and the possible generation of electrons by otherwise waste radiation. The momentum of a wave-front and some photo-electric phenomena are responsible for the suggestion, which has probably occurred to others. The velocity with which all matter is moving is also taken into consideration.

Partial Explanation.—In the theory of relativity, matter and energy are closely related, and an expression is forthcoming for the absolute energy of a moving body; whereas what has been always hitherto dealt with is the energy of relative motion. The absolute term in the expression for energy must be energy of constitution, and its form suggests a specialised portion of a turbulent ether circulating with the velocity of light. Turbulence confers upon an incompressible massive fluid the power of transmitting transverse waves.

All ordinary motions could then be regarded as only local modifications of this general ethereal circulation, in the same sort of way as a wind is a modification of molecular motion. Ordinary motion would be equivalent to change of mass, and might be expressed as a slight addition to the individualised and specific portion of ethereal circulation which constitutes the original mass. What we call matter would be the way in which this kind of localised ether motion appeals to our senses. In the case of an electron, the absolute term in the expression for energy exhibits itself to us quantitatively as the energy of its electrostatic charge.

Light is also a motion in the ether, and an advancing wave-front is known to exhibit some of the properties of matter; it also ejects electrons in a curious way. The problem, not yet solved, is to find a method of converting wave-energy into stationary vortex motion, which may be the converse operation to that of exciting light or X-rays by accelerating electrons. When light is generated, it has to advance at a certain speed. Whenever matter is generated, any surplus energy might account for its motion through space. All matter seems liable to be affected with considerable locomotive energy. If spiral nebulæ are dust clouds, their high velocities appear significant.

If all the motion of matter is a modification of circulatory constitutional motion, and if we can represent energy as a change of mass, it seems possible to represent all material phenomena as changes in the intrinsic rotational motion of the ether of space. This would have the advantage of being absolute, having reference only to a universal stationary ether, instead of being relative to other pieces of matter, which is the appearance that things present to our senses. Rotation even of matter has always had an absolute appearance; but rotation of ether is probably the real absolute, and may ultimately be expected to serve as a fundamental representation of universal phenomena.

* Abstract of Communication to Section A of the British Association at Liverpool, September 17, 1923.

The Hour of Meeting of the Institution of Electrical Engineers.—The recent post-card vote taken among the members of this Institution having addresses in the London district, shows that the majority of those who voted were in favour of 6 p.m. for the ordinary meetings of the Institution, and it has accordingly been decided to continue to meet at 6 p.m.

Anti-Dazzle Motor Car Headlight.—We recently witnessed a demonstration, organised by the Institute of Patentees, of an anti-dazzle motor-car headlight invented by Captain A. S. Ward. Two gas-filled bulbs are employed in this lamp, one at the top consuming 24 watts and the other at the bottom consuming 12 watts. The upper bulb is mounted in a cup-shaped reflector with its axis directed downwards and forwards at about 10 deg. with the horizontal and the lower bulb, which is also fitted in a cup-shaped reflector, is placed with its axis directed upwards and forwards at an angle of about 15 deg. with the vertical. At the back of the lamp there is a plane metal reflector, and curved reflectors are provided on each side. Normally only the upper bulb is used, the light being directed mainly downwards on to the road close in front of the car. Some of the light, however, is directed laterally by the side reflections to illuminate the footpath, and some is directed forwards by the plane mirror at the back of the lamp. The bottom bulb, which can be switched on when necessary, gives an upward beam which is useful for reading sign posts and also increases the illumination ahead and at the sides. An earlier form of the lamp has been granted the "Non-Dazzle" certificate by the R.A.C., and we are informed by the inventor that the lamp also complies with the proposed regulations of the Ministry of Transport for anti-dazzle headlamps. To us, the lamp appeared to be generally satisfactory with respect to dazzling effects, but we think that the forward illumination provided might usefully be increased if that can be done without introducing dazzle.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—While the general undertone is distinctly more cheerful the position as regards actual production is difficult to gauge, and in some sections a definite falling-off is recorded. Makers of cheap steel are more or less marking time until the Continental position is more settled. Rather better progress is being made in the direction of new business to take the place of expiring contracts. While the temporary "boom" arising in the early months of the year through the restriction of German production has dwindled out, contracts are still being placed in this district which normally would have gone to Germany. Combines directing the affairs of numerous small undertakings report that there are many inquiries for steel and steel products, though they tactfully omit to commit themselves as to the proportion of these materialising in actual business. Makers of open hearth steel are working to about 70 per cent. capacity, mainly on orders for transport and automobile engineers. The crucible steel branch is still severely depressed, though the increased volume of business being done in special alloys suggests that better times may be looked for. Several engineering firms are developing a sound connection in malleable iron and special castings. The tool trades are bright in patches. Here and there substantial contracts are under execution, mainly for the supply of spades, shovels, picks, forks, joiners' tools and saws. Continental competition in these branches is less marked, though American makers are offering stern opposition in overseas markets that formerly were largely British. The market for raw and semi-finished materials presents few new features except that the bulk of producers complain of the uniformly unremunerative nature of current quotations. Other districts in this country are offering keen competition for the small amount of new business that is in circulation. So far as forge and foundry iron are concerned this section will derive a certain measure of benefit from the decision to reduce the future contract price of blast-furnace coke from 26*s.* to 24*s.* per ton at the ovens.

South Yorkshire Coal Trade.—Schemes are in hand which will materially strengthen local output in the near future. Meanwhile collieries are working full time and except for transport delays have little difficulty in disposing of the bulk of their output. The improvement reported last week in house coal is well maintained. Current inquiries indicate that a substantial expansion in demand may be looked for during the closing months of the year. Exporters continue big buyers of best steam hards. Slacks are going away very freely. Cobbles and nuts are realising the full market quotation, and steady business is proceeding in all qualities of coke. Quotations :—Best branch handpicked, 29*s.* 6*d.* to 31*s.*; Barnsley best Silkstone, 26*s.* 6*d.* to 28*s.*; Derbyshire best brights, 25*s.* to 27*s.*; Derbyshire best house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire best large nuts, 20*s.* to 21*s.* 6*d* ; Derbyshire best small nuts, 15*s.* to 16*s.*; Yorkshire hards, 21*s.* to 23*s.*; Derbyshire hards, 20*s.* to 22*s.*; rough slacks, 11*s.* 6*d* to 13*s.* 6*d.*; nutty slacks, 10*s.* to 12*s.*; smalls, 7*s.* to 9*s.*

The Institution of Heating and Ventilating Engineers.—This Institution, whose address is 38, Victoria-street, S.W. 1, announces a series of meetings during the winter session, for the reading and discussion of papers. The meetings commenced on the 9th inst.

The Late Mr. Henri Schneider.—On Sunday, September 30, a statue erected to the memory of Mr. Henri Schneider, the son of the founder of Creusot Works, was unveiled in the town of Creusot. Mr. Henri Schneider died on May 17, 1898. A fund for erecting a statue to his memory had long been started among the workmen and staff forming part of the numerous establishments now owned by the firm, but the actual function was greatly delayed by the war and its after effects. The matter commenced and remained to the end a private one, involving solely the family of Mr. Schneider and the wider family consisting of the numerous employees of all grades who belong to the different Schneider establishments. The first speaker at the ceremony was Mr. E. Schneider who thanked the promoters and the Creusot population for the fresh proof they were giving that day of their affection for his family and of their attachment to the Creusot Works. He was followed by the president of the fund; then by Mr. Julliotte, a former manager of Creusot Works, who gave a brief review of the numerous industrial activities of his late chief. The concluding speeches were most appropriately entrusted to one of the works' pensioners and to a pupil of the Schneider Arts and Crafts Schools, who both dealt with the philanthropic work carried out by the deceased. The statue is erected on an open space facing the large hospital and surgery which Mr. H. Schneider built in 1894 for sick and injured workmen and inhabitants of the district, an institution which, thanks to his son, Mr. E. Schneider, and members of the Schneider family, has since kept pace with every improvement in medical science and surgery. No better position could have been selected. We need not enter here into the French distinctions which were granted to Mr. H. Schneider at different times; we may add, however, that he was an honorary member of the Institution of Civil Engineers. He became a member of the Iron and Steel Institute in 1876; he was awarded the Bessemer medal in 1889, and was elected a member of Council of the Institute in 1890. Mr. H. Schneider received the members of the Institute at Creusot after the meetings in the years 1878 and 1889 in Paris.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Sales of Cleveland pig-iron show expansion, and an encouraging feature is the renewal of a fair amount of forward buying. Contracts for delivery to the end of the year have been made, and there are inquiries circulating for supplies over the first quarter of 1924. No. 1 is extremely scarce and continues to command 102*s.* 6*d.*; No. 3 is quoted 96*s.*, though some makers hold out for a higher figure; foundry 4 is on sale at 91*s.*; and No. 4 forge is quoted 88*s.*, f.o.t. makers' works, and f.o.b. Tees.

Hematite.—Continued good demand for East Coast hematite is stiffening values and reducing stocks. The position of producers is thus much improved, and they are not pressing iron on the market anything like so persistently as they were a little while ago. Continental inquiries are unabated, and home needs are expanding. Whilst customers state they can still place orders for home purposes, and for shipment overseas at 99*s.* for Nos. 1, 2 and 3, some makers are now holding out for a rather higher figure.

Foreign Ore.—There is a little more doing in foreign ore. Market rates remain on the basis of 23*s.* c.i.f. Tees for best rubio.

Blast-furnacemen's Wages Reduced.—The average net selling price of No. 3 Cleveland pig-iron for the third quarter of the year having been certified at 99*s.* 7·72*d.*, as compared with 112*s.* 1·64*d.* per ton for the previous three months, North-East Coast blast-furnacemen's wages are reduced by 12·50 (12½) per cent., lowering wages from 50·50 (50½) per cent. above the standard to 38 per cent. above the standard.

Ironstone Miners' Wages Lowered.—On the ascertained price of Cleveland pig-iron for the third quarter of the year it is computed that ironstone miners' wages should be lowered by 15·62 per cent., but the mineowners and miners' representatives have agreed to a drop of 13 per cent., leaving wages at 89·5 per cent. above the base rate. The figure represents an advantage for the miners of 5 per cent. more than the old sliding scale would have given.

Manufactured Iron and Steel.—Some improvement is reported in several branches of finished iron and steel. One or two fairly substantial home and export steel contracts are understood to have been secured, and inquiries are on a rather better scale. Common iron bars are 12*l.*; iron rivets, 14*l.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.*; steel ship, bridge and tank plates, 9*l.* 15*s.*; steel angles, joists and heavy sections of rails, 9*l.* 10*s.*; fish plates, 12*l.* 10*s.*; black sheets, 15*l.*; and galvanised corrugated sheets, 19*l.* 5*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The position of things in the Scottish steel trade has not changed, and conditions are as bad as ever. A more hopeful reading is being taken of the possibility of an early termination of the boiler-makers' dispute, and if that good news should come along soon it will have a marked effect on the steel trade. No rush of orders can be anticipated yet awhile, but a gradual improvement would be forthcoming. At the present time a very meagre demand exists all round, but inquiries are expanding somewhat, largely on export account. In the black sheet trade there has been no change over the week, and the bulk of the business passing is still for the lighter gauges. Prices are steady and are as follow:—Boiler plates, 13*l.* per ton; ship plates, 10*l.* per ton; sections, 9*l.* 15*s.* per ton; and sheets, 12*l.* 10*s.* per ton—all delivered Glasgow stations.

Malleable Iron Trade.—A very quiet state prevails in the majority of the malleable iron works in the West of Scotland, and dealings are not of much volume. Not only is bar iron in poor request, but the re-rolled steel branches are also very quiet. The export side is very dull. Prices show no change with "Crown" bars called 12*l.* per ton, delivered Glasgow stations, and about 11*l.* 5*s.* per ton f.o.b.

Scottish Pig-Iron Trade.—There is little fresh to report in connection with the Scottish pig-iron trade, and the demand still falls considerably short of the output. A few lines were recently booked for hematite iron, but foundry grades continue slow of sale and there would seem to be little prospect of any immediate improvement. The following are the market quotations:—Hematite, 5*l.* 5*s.* per ton, delivered at the steel works; foundry iron, No. 1, 5*l.* 3*s.* 9*d.* per ton, and No. 3, 4*l.* 18*s.* 9*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The shipment of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, October 6, was 864 tons. Of the total, 829 tons went overseas and 35 tons went coastwise. For the corresponding week last year the figures were 1,110 tons abroad and 40 tons coastwise, making a total shipment of 1,150 tons.

Institution of Engineers and Shipbuilders in Scotland.—During the new session of the Institution of Engineers and Shipbuilders in Scotland, which commences on Tuesday next, October 16, the following papers will be read and discussed: "Losses in the Component Parts of a Three-Stage Turbine Pump," to be submitted by Dr. W. Blackadder; "Auxiliary Machinery for Diesel-Engined Vessels," by Mr. Robert Love; "Pipe Bending by Machinery," by Mr. Carl R. H. Bonn; "The Board of Trade and Merchant Shipping," by Mr. Frank R. Blair; "Tests on a Cylindrical Marine Boiler With and Without Preheated Air," by Mr. W. H. Owen"; "Subdivision of Ships," by Mr. J. Foster King; "The Economic Powering of Motor Ships by a New Design of Oil Engine," by Mr. A. E. L. Chorlton, M.Inst.C.E.; "Manœuvring of Ships" (Part II), "Unbalanced Rudders of Twin-Screw Ships," by Mr. G. S. Baker and Mr. G. H. Bottomley; "Efficiency in Ship Construction from the Strength Point of View," by Dr. J. Bruhn; "Modern Pumping Machinery in Holland," by Professor J. C. Dijxhoorn; "Monel Metal: Its Origin, Properties and Uses," by Engineer Rear-Admiral W. J. Anstey, C.B., R.N. (Retired); "Modern Appliances for the Handling of Coal in the Harbour of Rotterdam," by Professor F. Westendorp; and "Sliding Cylinder Double-Acting Diesel Engines," by Mr. John C. M. MacLagan. The "James Watt" dinner of the Institution will be held in the Grosvenor Restaurant, Gordon-street, Glasgow, on Friday, November 30.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The colliery workers at the Nine Mile Point Colliery, owned by the United National Colliery Company, have been informed "that owing to the serious loss sustained by the company, due to the prohibitive cost of work, they find it impossible to continue carrying on the colliery, and they have no alternative but to close down at the end of the current month." About 2,000 men are employed at the colliery, and including their families over 5,000 people are affected. The men have been personaly given fourteen days' notice. Except that best small coals have become rather less plentiful owing to temporary stoppages having curtailed production, there is no change of importance in the general position of the coal market. Supplies of most grades are still adequate to meet exporters' requirements and prices continue irregular and dependent on individual circumstances. Best Admiralty large is round 28*s.* with leading Monmouthshires from 26*s.* to 27*s.* 6*d.* Best bunker smalls are steady at 18*s.* to 19*s.*, but other grades were still in ample supply and ranged from 13*s.* to 17*s.* Exports of coal as cargo from South Wales in September amounted to 2,273,771 tons, or 102,749 tons less than in August. Shipments from Cardiff totalled 1,300,857 tons, a decrease of 104,883 tons; from Newport 416,051 tons, a drop of 7,993 tons; from Swansea 282,245 tons, a decline of 21,854 tons; and from Llanelly 34,310 tons, a fall of 9,893 tons; but those from Port Talbot at 240,308 tons represented an increase of 25,688 tons. Exports to Italy, British coaling depots, United States of America, Belgium and Holland were greater than in August, but to other destinations were decreased, particularly to France, where they dropped to the extent of 70,134 tons, and Spain, with a reduction of 39,390 tons. Shipments to France in September amounted to 876,965 tons, to Italy 383,034 tons, to South America 276,930 tons, to Spain 112,076 tons, to Portugal 65,145 tons, to Greece 27,857 tons, to British coaling depots 161,002 tons, to United States of America 24,382 tons, to Canada 11,895 tons, to Belgium 74,529 tons, to Holland 80,619 tons, to Germany 43,887 tons, and to other countries 135,450 tons. Mr. H. H. Evans, J.P., Cilfynydd, Pontypridd, agent to the Albion Steam Coal Company, Limited, has been appointed general manager of the Cambrian Combine Collieries in succession to Mr. Hedley Clark, J.P., who resigned at the end of September. Mr. Evans is conversant with all phases of colliery work. He started work as a collier when twelve years of age. After working underground he became a pupil surveyor and mining student and eventually became manager of the Bwllfa Colliery and subsequently agent to the Albion Steam Coal Company.

Iron and Steel.—Exports of iron and steel goods last week amounted to only 9,415 tons, compared with 92,647 tons in the preceding week. Shipments of tin plates and terne plates amounted to 5,448 tons, against 10,419 tons; black plates and sheets to 3,435 tons, against 2,201 tons; galvanised sheets to 503 tons, against 2,259 tons; and other iron and steel goods to 139 tons, against 7,768 tons.

BALANCE-SHEET OF A RÖCHLING-RODENHAUSER INDUCTION STEEL FURNACE.—The performance of an electric furnace is not easily put to a quantitative test, and balance-sheets are hence very rarely published. In "Stahl und Eisen," of August 23, O. von Keil and W. Rohlund give particulars of the tests of a Röchling-Rodenhauser steel furnace, having two channels and two induction coils and supplied from a three-phase circuit on the Scott system with current of 200 amperes at 6,000 volts and 16·6 periods per second. The capacity of the furnace was 12 tons. In addition to the electric measurements, temperatures were determined by means of a radiation pyrometer, and thermocouples were distributed so as to allow also of the determination of heat losses by radiation and conduction. The volume and temperature of the cooling air were also measured, and analyses were made during the heat of 4 hours of 11 steel samples, 8 slag samples and 10 gas samples. The thermal efficiency of 62 per cent. was satisfactory for electric furnaces, and would have been higher still if the channels had been better covered with dolomite; the current consumption, 256 kw.-hours per ton of steel, it is claimed could thus have been reduced by 12 per cent. The electric efficiency of the furnace was rather low, 60 per cent., mainly owing to the low average value of the $\cos \phi$, 0.35; the furnace and the copper coils had been designed for a higher power factor, and with smaller copper losses this efficiency might easily have been raised considerably.

NOTICES OF MEETINGS.

THE MANCHESTER ASSOCIATION OF ENGINEERS.—Friday, October 12, at 7 p.m., at the Memorial Hall, Albert-square, Manchester. Inaugural Address by the president, Mr. Cecil Bentham, M.I.Mech.E.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, October 12, at 7.30 p.m., at 39, Victoria-street, S.W. 1. Ordinary Meeting. Paper on the "Never-Stop Railway," by Mr. W. Yorath Lewis, M.I.Mech.E. Saturday, October 13, at 2 p.m., visit to the works of the Gas Light and Coke Company, at Beckton. Friday, October 19, at 39, Victoria-street, at 7.30 p.m. Lecturette, "The Gas Boiler (or Circulator) and Its Application," by Mr. F. W. Dye.

THE KEIGHLEY ASSOCIATION OF ENGINEERS.—Saturday, October 13, at 6.30 p.m., in the Assembly Room, Cycling Club, Cavendish-street, Keighley. Lecture: "Hardness and Its Measurements," by Professor G. F. Charnock, M.Inst.C.E.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.—Saturday October 13, at 2 p.m., in the Lecture Hall of the Institute, Newcastle-upon-Tyne. Discussion on "The Permian Formation in East Durham," by Mr. W. O. Wood; "Vertical and Lateral Variations in the Composition of Bituminous Coal Seams," by Professor Henry Briggs, B.Sc., Ph.D.

THE MINING INSTITUTE OF SCOTLAND.—Saturday, October 13, at 3 p.m., in the Heriot Watt College, Chambers-street, Edinburgh. Discussion on "Economy and Efficiency of Ventilation," by Mr. Joseph Parker. "A Volcano in the Bathgate Coalfield of West Lothian, by Mr. H. M. Cadell; "The Hurlet Sequence in Renfrewshire and Dumbartonshire, and the Evidence of Basin Structure in the Coalfields of Scotland," by Mr. David Ferguson; "Coal Conveyors," by Mr. William G. Burt.

THE INSTITUTE OF METALS.—Birmingham Local Sections, Tuesday, October 16, at 7 p.m., in the Chamber of Commerce, New-street. Address by Mr. F. Johnso D.Sc., Chairman.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, October 16, at Elmbank-crescent, Glasgow. Presidential Address by Mr. J. Howden Hume; after which Dr. W. Blackadder will read a paper on "Losses in the Component Parts of a Three-Stage Turbine Pump."

THE INSTITUTION OF PRODUCTION ENGINEERS.—Wednesday, October 17, at 7 p.m. for 7.30 p.m., the Annual General Meeting of the Institution will be held at the Engineers' Club, Coventry-street, London, W. 1. Mr. J. D. Scaife, of Coddington Hall, near Newark, president of the Institution for the year 1923–24, will deliver his Presidential Address, which will be followed by a Smoking Concert.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, October 17, at 5 p.m., at 49, Cromwell-road, South Kensington. A discussion will be held on a paper by Sir Napier Shaw, F.R.S., and Captain D. Brunt, "Towards a basis of Meteorological Theory: Thirty-nine Articles of Condition for the Middle Atmosphere."

THE SOCIETY OF GLASS TECHNOLOGY.—Wednesday, October 17, at 3 p.m., in the Applied Science Department, The University, St. George's-square, Sheffield. Award of the "Frank Wood" medal, and to receive and discuss the following papers: (*a*) "The Effect of Titania on the Properties of Glass," by Mr. A. R. Sheen, B.Sc.Tech., and Professor W. E. S. Turner, D.Sc.; (*b*) "The Estimation of Selenium in Glass," by Mr. A. Cousen, B.Sc., A.R.C.Sc.

THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—Thursday, October 18, at 2.15 p.m., in the Mappin Hall, Sheffield University, St. George's-square, Sheffield. "The Position of Mechanical Engineering in Colliery Operations," by Sir Wm. Ellis, D.Eng., M.Inst.C.E. Paper open for discussion, "American Coal-Mining," by Mr. J. A. S. Ritson.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, October 18, at 6 p.m., Presidential Address by Dr. A. Russell, M.A.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, October 19, at 6 p.m., Presidential Address by Sir John Dewrance, K.B.E.

THE INSTITUTE OF METALS.—Scottish Local Sections, Friday, October 19, at 7.30 p.m., at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. Paper on "Large Metallic Crystals and Some of their Properties," by Professor H. C. H. Carpenter, F.R.S.

THE INSTITUTE OF PHYSICS.—The fifth of the series of public lectures on Physics in Industry, dealing with "Physics in the Textile Industries," will be delivered by Dr. A. E. Oxley, physicist to the British Cotton Industries Research Association, at the Institution of Electrical Engineers, on Monday, the 22nd inst., at 5.30 p.m. The chair will be taken by Sir Charles Parsons, who has just succeeded Sir J. J. Thomson as president of the Institute.

THE NATIONAL ASSOCIATION OF SUPERVISING ELECTRICIANS.—The winter session of this association was inaugurated on Tuesday last, October 9, by a lantern lecture, given by Mr. J. L. Chaloner, on the subject of "Present-Day Heavy Oil Engines." The meeting was held at St. Brides' Institute, the president, Mr. W. E. Highfield, occupying the chair. The lecturer gave a very complete and well-balanced account of the various types of engine which have been developed for using heavy oil as fuel, and an interesting discussion followed.

SINGLE-RUNNER OVERHUNG PELTON TURBINES AT FAGUNDES, BRAZIL.

CONSTRUCTED BY THE PELTON WATER WHEEL COMPANY, ENGINEERS, SAN FRANCISCO, CAL., U.S.A.

(*For Description, see Page* 461.)

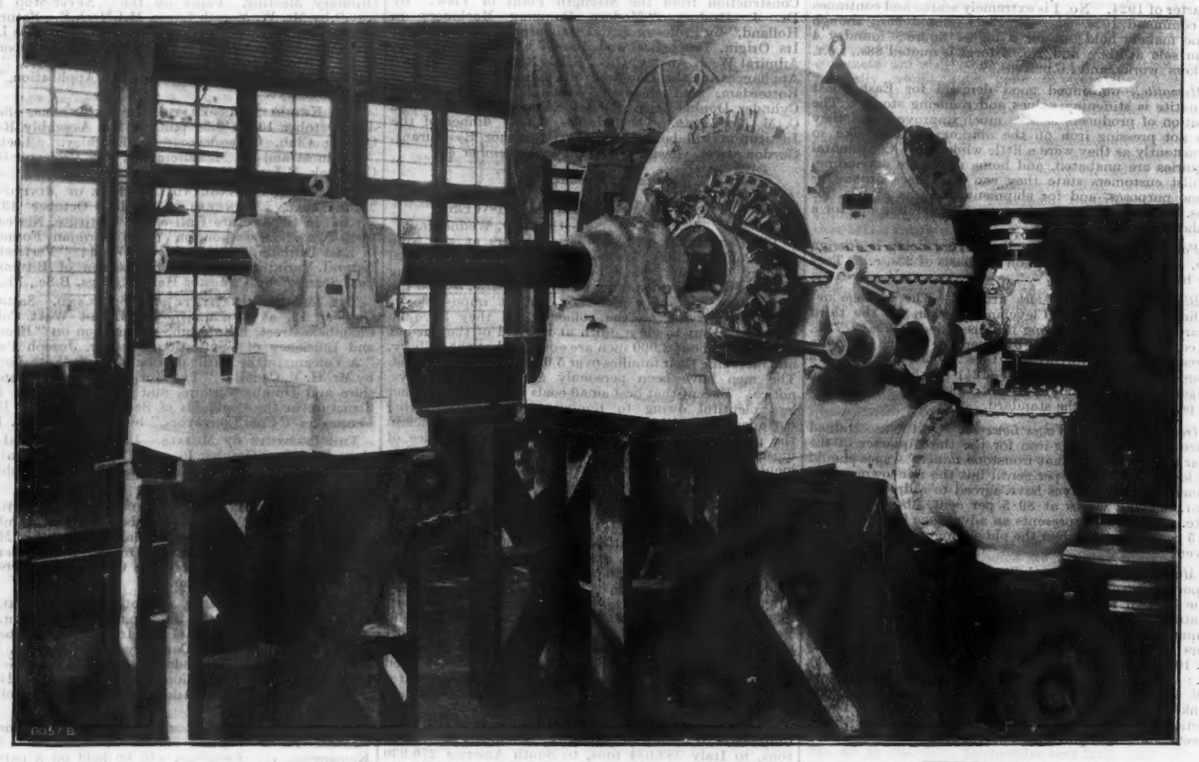


Fig. 2. Turbine showing Gate Operating Mechanism.

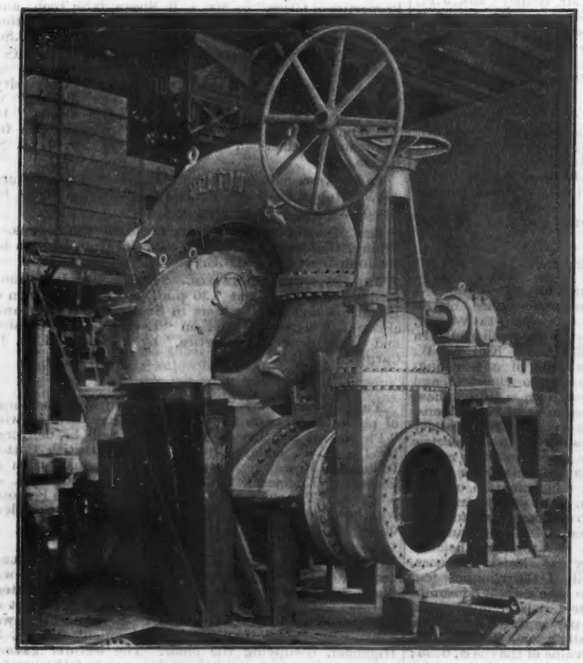


Fig. 3. General View of Turbine.

Fig. 4. Governor of Turbine.

CARRIAGE BUILDING AT THE DERBY WORKS OF THE LONDON MIDLAND AND SCOTTISH RAILWAY.

MR. R. W. REID, M.I.MECH.E., CARRIAGE AND WAGON SUPERINTENDENT.

(*For Description, see Page* 467.)

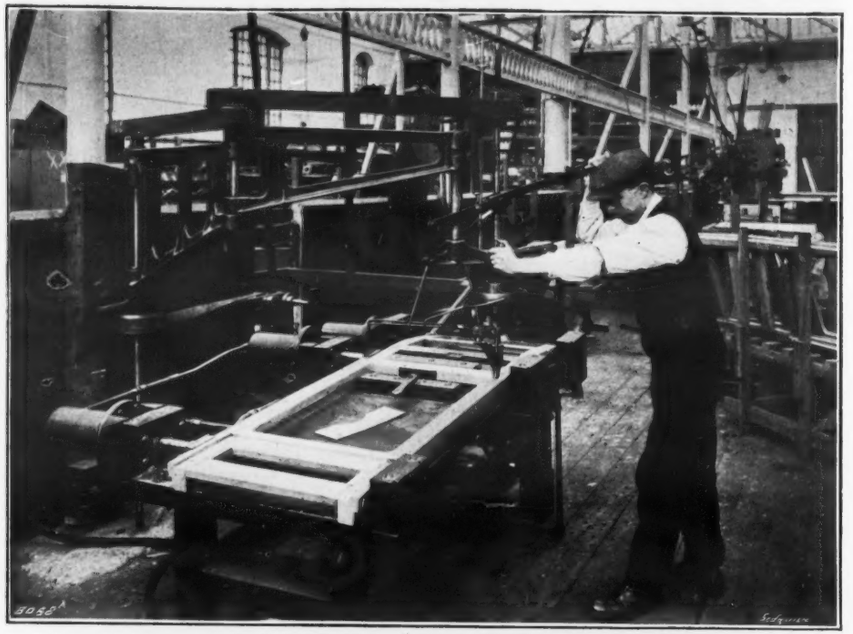


Fig. 1. Cramping and Screwing Doors.

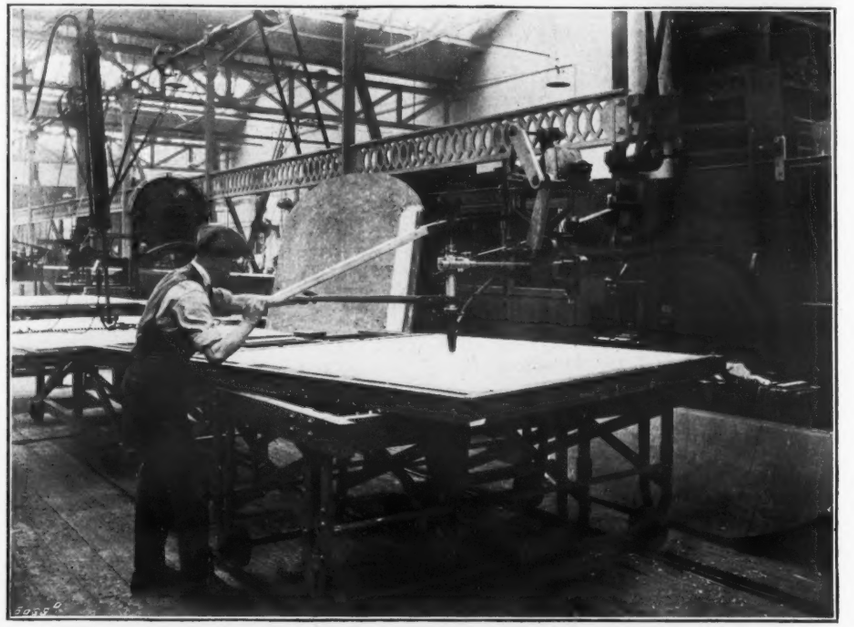


Fig. 2. Screwing Carriage Partitions in Jig.

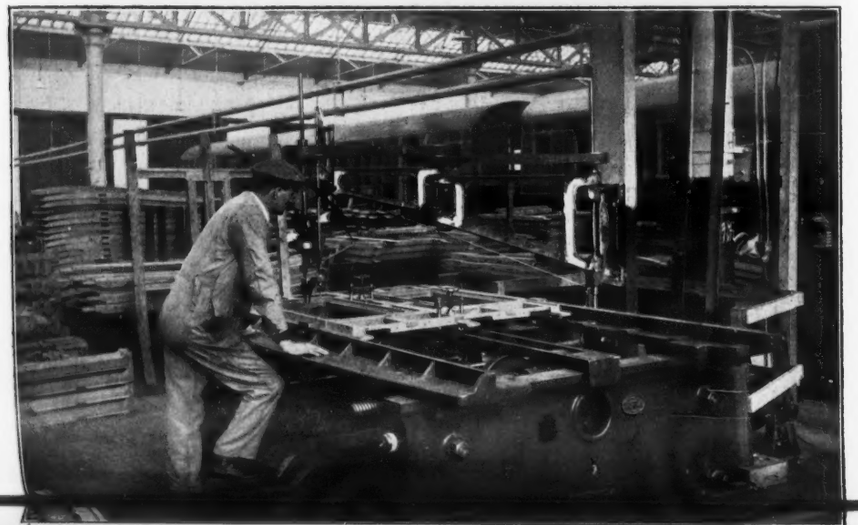


Fig. 3. Cramping and Screwing Quarters.

Fig. 4. Making Carriage End Frames.

Fig. 5. Assembling and Cramping Floor Framing.

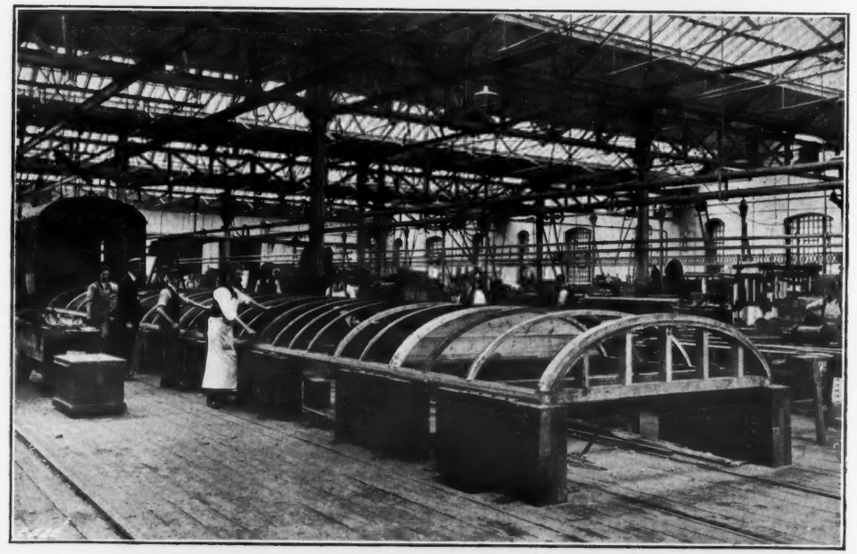


Fig. 6. Fixing Roof Sticks and Angles on Roof Jig.

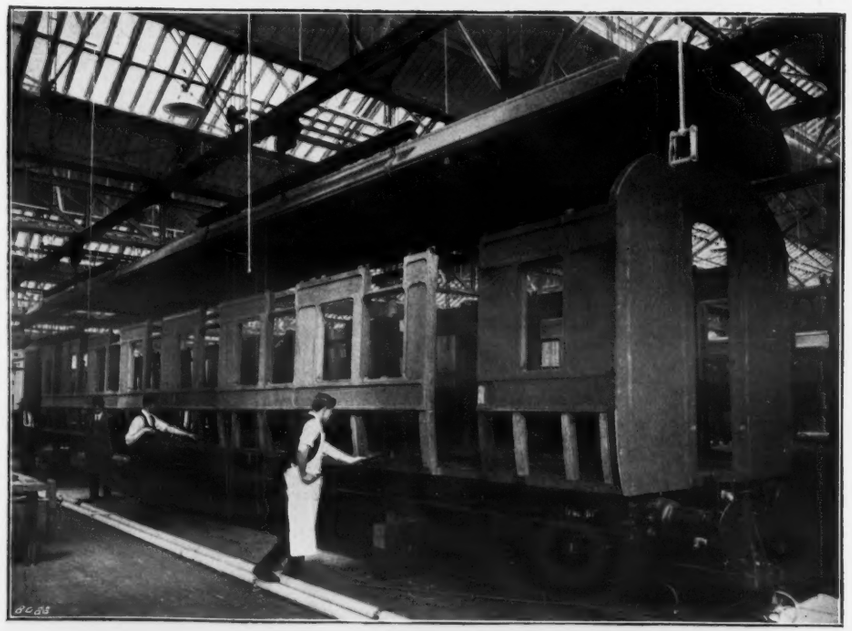


Fig. 7. Cramping Framing in Position.

Fig. 8. Roof Ready for Transport to Body.

ENGINEERING.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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Two-Page Plate.—CARRIAGE BUILDING AT THE DERBY WORKS OF THE LONDON, MIDLAND AND SCOTTISH RAILWAY.

ENGINEERING.

FRIDAY, OCTOBER 12, 1923.

THE DEVELOPMENT OF ELECTRICITY SUPPLY.

So much has been said in the past by engineers about the futility of our earlier methods of dealing with the administrative side of electricity supply and about the folly of restricting technical possibilities to small areas which have been demarked for purely political or by chance considerations, that even the lay press and general public have come to a vague appreciation of the necessity for some drastic change in method. Nowadays one would have to search for the man who would deny the necessity for some scheme of unification and some procedure which will enable the country to obtain full advantage from the possibilities of modern electrical methods. In this happy case it might be supposed that the only handicap to the full fruition of the Electricity Act of 1919 would be the difficulty of deciding which of the rival claimants to its advantages should have first attention. Experience has shown, however, that a benediction in general terms does not necessarily mean that the chairman of the electricity committee of a corporation, or the chief engineer of a supply company, is prepared to recommend his committee, or his company, to embrace the application of the Act to their particular case too eagerly.

The main purpose of the Act of 1919 was to set up a series of electricity districts, covering the country, in each of which there should be some body to deal with the business of electricity supply as a whole. The carrying out of the Act has not proved a simple matter. In many of the districts demarked by the Electricity Commissioners the formation of any such central body is proving very difficult owing to the claims and counter-claims of various existing contributors who would be affected under any scheme of unification. This difficulty is, however, not necessarily evidence that the general support accorded to the underlying idea of the Act is insecure. The first duty of the servant of either a corporation or a company is to his employers, and it is his business to ensure that they shall obtain the best terms possible in any scheme of combination. The delays and hitches are evidence rather of the inherent difficulties of the question than of opposition to the general scheme of the Act.

This state of affairs, while explicable and understandable, is none the less unfortunate. Electricity generation and supply in this country has always suffered vicariously for various outside interests in which it inherently has no concern, and the process is apparently to continue. In their third annual report, which has just been issued, the Electricity Commissioners state that "only in a few districts where the circumstances are exceptional will it be found practicable to formulate and give effect to an engineering scheme of reorganisation dictated by electrical considerations alone. In the majority of cases the engineering problem had not proved capable of dissociation from the particular interests of the various authorities in a district, with the result that compromise has been necessary." This statement will not surprise anyone who has any knowledge of the history of electricity supply in this country, and the chief consolation to be drawn from it, and the situation to which it refers, is that the matters are not so bad as they would have been if the Act of 1919 had never been passed, and that the existence of the Electricity Commission pushes the technical argument into a more prominent position than it occupied in the past.

In spite of difficulties which have to be met and compromises which have to be accepted, considerable progress is being made towards a more rational basis for electricity supply, and the record which the Commissioners are able to give in their third report is not unsatisfactory in view of the inherent difficulties of the question with which they are dealing and what is after all the comparatively brief period over which they have been operating. Although the main business of the Commissioners is to get the various electricity districts working under central bodies, they have many ancillary duties, and their record in connection with some of these shows that the technical aspects of electricity supply are steadily improving. It is interesting and satisfactory to note, for instance, that on March 31 last, which is the date terminating the period covered by the report, 174 authorised undertakers were taking or exchanging bulk supplies. There are in all some 500 authorised undertakers in the country, so that this figure of 174 indicates that inter-working is now taking place to a very considerable extent. Another illustration of the same tendency in the direction of eliminating uneconomical plant is given by the announcement that, since the early part of 1920, 30 generating stations, 18 owned by local authorities and 12 by companies, have either been shut down entirely or relegated to the position of stand-by stations. Since January, 1920, a gross addition of 1,279,088 kw. of generating plant has been authorised, of which about 90 per cent. is for use in England. This gross addition is somewhat greater than the net addition, as in some cases inefficient or obsolete plant has been replaced by the new plant sanctioned. This figure of 1,279,088 kw. does not include plant for Ireland after 1922, as in that year the administration of the electricity services in that country was transferred to the Northern and Southern Governments. This large figure of over one million and a-quarter kilowatts represents a very considerable advance, and shows that electricity supply has advanced very materially even in an unfavourable period.

On the main question of the establishment of Electricity Districts the Commissioners are able to report the definite carrying through of three schemes. There are those constituting a central body for the South-West Midlands District, the South-East Lancashire District, and the North Wales and South Cheshire District. None of these schemes had been finally approved by the Minister of Transport and Parliament by March 31 last,

which terminates the period officially covered by the report, but all passed all their final stages in the course of the summer. In the cases of the two first Districts, schemes for the creation of Advisory Boards have been sanctioned, this being an alternative to the formation of a Joint Authority, which is allowed under the Act. The most important supply undertakers concerned in the South-West Midlands District are the Birmingham Corporation, the Shropshire, Worcestershire and Staffordshire Electric Power Company, and the Worcester Corporation. The district is a comparatively simple one, and under the scheme is ultimately to be supplied from the stations of these three main authorities, the existing stations at Dudley, Kidderminster, Ludlow, Malvern, Redditch and Sutton Coldfield being ultimately closed down. The most important new provision under the scheme is for the running of various transmission lines and the erection of a new 150,000 kw. station by the Birmingham Corporation at Hams Hall.

The South-East Lancashire District is somewhat more complicated and covers the areas of a large number of important authorities, among which are the Manchester, Salford, Bolton, Bury, Oldham, Rochdale, Stockport and Wigan Corporations, the Stalybridge, Hyde, Mossley and Dukinfield Tramway and Electricity Board, the Lancashire Electric Power Company, and the South Lancashire Tramways Company. Some eleven or twelve smaller corporation or company supplies are also concerned, as is the London, Midland and Scottish Railway Company in virtue of its generating station at Clifton Junction. The fact that it has been possible to bring an agreed scheme into operation in a complicated area of this character must be a source of satisfaction to the Commissioners, and suggests that even the problems presented by the most difficult districts will prove capable of solution. The scheme covers the shutting down of small stations at Bury, Eccles, Glossop, Heywood, Dickenson-street, Manchester, Radcliffe, Sale and Stretford, and the ultimate building of new stations by the Manchester, Oldham, Wigan and Stockport Corporations, the Stalybridge Board and the Lancashire Power Company. Many new main transmission lines are to be erected in connection with the scheme of development.

Quite a different solution of the difficulties of unification has been adopted in the case of the North Wales District, a Joint Electricity Authority having been formed, which is, however, to delegate most of its administrative duties to the North Wales Power Company. The power and duties reserved to the Joint Authority concern such matters as the promotion and opposition of Parliamentary Bills, the institution and defence of legal proceedings, to right of entry and inspection of works of authorised undertakers in the District, and the power to require returns from them, etc. This scheme is a very interesting one and has the great advantage that the actual running of the business of electricity generation and distribution, which is the basis of this and all the other schemes, is left in the hands of private enterprise, while outsiders and the smaller authorities who are concerned have their interests properly guarded by the existence of the Joint Authority. The original scheme covered the area of the Chester Corporation, but it was found impossible to obtain any agreement between this body and the power company, and the area was finally modified to exclude Chester. It is not clear whether the Chester district is ultimately to be formed into an independent Electricity District or whether it will later be attached to some other area.

STANDARD PARTS IN MOTOR CAR DESIGN.

The standardisation of the design of any machine is the first step towards its economic production. That truism would be accepted by most people who have to deal with repetitive manufacturing processes, and its emphasis by the specification of individual cases, whether of certain makes of motor vehicles, sewing machines, Diesel engines or ships, would not add much to the weight of a statement which embodies the general experience of all. The magnitude of the savings effected by its introduction is an entirely different matter, for it depends upon the way in which the standardisation is carried out. To consider one important point, a firm may decide upon the production of a certain machine from standard parts made in their own works and thus reduce the costs of manufacture. That may, however, be done without paying any attention to the use of parts of sizes standardised within the entire industry. The production of miscellaneous components to the individual taste of the designer has to be paid for by the user, not only in the first cost of the machine but also in heavier charges for replacements. Were the standards adopted common to the trade a great saving could be effected in many ways.

The automobile industry is fast becoming convinced of the necessity for effecting every economy possible by this means, and this is evident from the presidential address which Mr. H. G. Burford delivered before the Institution of Automobile Engineers on Wednesday last. He thought that it was probable that the fundamental reason why greater progress had not been made with the general standardisation of automobile parts was that many firms failed to recognise both its importance and its scope. Standardisation of details was possible without the introduction of any necessity for limiting the individual characteristics of any type of car. With such a scheme in operation the draughtsman need not spend time drawing out step brackets, lamp brackets, radiator drain cocks and similar small fittings which can be more cheaply produced in thousands for general use. Dies, jigs and patterns can all be saved, and economies may also be effected by adopting standard bolts and nuts rather than have them of unusual dimensions for little or no definite reason.

Economies must be effected if British cars must meet foreign competition, which becomes more intense as time goes on. Anything to cheapen production, therefore, demands consideration, and the standardisation of parts is one of the simplest and most readily attainable means to that end. Mr. Burford summarised the advantages of the system on the two sides of the industry, those of manufacturing and selling and also to the user in dealing with the maintenance of the equipment in running and efficient order. In making an appeal to the manufacturers he contended that all the work and energy expended in preparing a general scheme is practically wasted if only a few firms adopt the standards. The standards department of the Society of Motor Manufacturers and Traders has been put on a proper footing, and looks for assistance from the members of the technical staffs of the individual firms in the way of suggesting parts for standardisation and offering criticism of the suggestions put forward. The work of international standardisation has not been neglected, and much is being done by Mr. T. H. Woollen through the society. Already France, Italy, Belgium, the United States and Great Britain have agreed to certain proposals, and general adoption of others will take place as each component comes up for review.

Mr. Burford also made some suggestions in his address, regarding road construction for modern traffic. The annual expenditure on this necessary work is now about double the amount spent prior to the war. The incidence of the financial burden upon the tax-payer, the ratepayer and special users should, he thought, be the subject of investigation by an impartial and responsible Parlimentary tribunal. One question which Mr. Burford suggested required most careful consideration was how far it was really economic to spend large sums every year on the surface improvement and maintenance of old and entirely unsuitable roads, instead of capitalising the grants available and utilising them for complete reconstruction on modern lines.

THE ORIGIN OF PETROLEUM.

The question of the origin of petroleum generally comes up when the variations in the composition and properties of petroleum from different wells and different depths of the same field are being discussed. The problem is very complex. In many cases we have reason to believe that the petroleum was not formed in the strata in which we find it. The bulk of the oil of a field may have been produced under fairly uniform conditions; but each minor occurrence may also have passed through its own history of production and development under special local conditions. As regards parent material or materials, we have only suppositions. The oils—as distinct from petroleum—we commonly deal with are all of organic origin, vegetable or animal. Petroleum may have the same origin, and of late the view has been gaining ground that the occurrences of petroleum and coal are interrelated. But the advocates of an animal origin of petroleum have by no means given in: the possibility of an inorganic origin also continues to find support, and the great variety of petroleums suggests various parent materials and modes of production. At present there is no agreement, not even on essential points.

The Institution of Petroleum Technologists last Tuesday devoted the opening meeting of the winter session to a discussion of this problem. Mr. E. H. Cunningham-Craig, B.A., F.G.S., F.R.S.E., who introduced the discussion by a paper on "Recent Researches bearing upon the Origin of Petroleum," dismissed the two theories of an inorganic origin in a few words. The hypogene theory, that hydrocarbons were liberated by the action of water upon the metallic carbides beneath the outer crust of the Earth—a kind of acetylene-condensation theory—he considered merely a speculative idea, and the vague suggestion of a volcanic origin of oil was open to at least two mutually-contradictory interpretations—a favourite argument of geologists, Dr. Ormandy subsequently objected; Mr. Cunningham-Craig migh thave retorted, not for geologists only. Mr. Cunningham-Craig's statement that geologists generally favoured the vegetable origin, and chemists the animal origin, was perhaps too sweeping. He, at any rate, is a decided adherent of the vegetable theory or of some association of coal with natural oil, and he made out what Mr. H. Barringer, the President of the Institution of Petroleum Technologists, considered a good case.

Years ago, Mr. Craig pointed out that the three main oil-bearing horizons of Trinidad had each a carbonaceous phase in some other districts, and that petroliferous and carbonaceous phases approached one another closely in some districts. Similar evidence had been forthcoming from Venezuela, Assam, Hungary, Rumania and other countries in which the coal and oil-bearing series overlapped, the coal increasing in the upper strata, the oil in the lower. Unpublished evidence of the same kind had been brought to light in this country during the war. At d'Arcy, near Dalkeith, a well had been drilled, on Mr. Craig's suggestion on the assumption that oil shale denoted petroleum which was dead and buried, and that beneath the oil-shale series free petroleum would still be found. The oil had been found, though in small quantities, within 10 ft. of the depths predicted.

Mr. Cunningham-Craig next referred to the hydrogenation of coal by F. Bergius. By treating, a coal containing a fair amount of volatile matter with hydrogen under high pressure (up to 5,000 lb. per square inch) at temperatures up to 850 deg. F., an exothermic reaction was induced, part of the solid fuel was liquefied and a product indistinguishable from heavy crude petroleum was obtained. When we first mentioned the experiments of Bergius, on page 262 of our issue of August 22, 1913, he had treated wood and coal with water and hydrogen in an autoclave; later he prepared hydrogen by enclosing iron and water in his autoclave; the experiments are now repeated in this country. Mr. Craig admitted that the Bergius process for making heavy and also lighter oils (starting from heavy oils) was not yet a commercial proposition; but it opened out great possibilities. Coal was a finished product containing carbon and a little hydrogen; if we supplied more hydrogen, hydrocarbon oils could be formed. The reaction being exothermic, heat should only be used to start the reaction; the pressures that Mr. Craig had calculated as necessary were within the range of the experiments of Bergius. In Nature vegetable matter would, before reaching the coal stage, contain sufficient hydrocarbon for the reaction to start at suitable pressure; the heat engendered would check the reaction, which might, however, restart or continue while the heat was conducted away.

Passing to another point, Mr. Cunningham-Craig

referred to the many gradations of vegetable deposits between peat and anthracite. The purest coal attained the coal stage earliest; the cannels—impure with much inorganic matter in a finely-divided state—contained their vegetable matter in a "jetonised" lignitic condition, and yielded most oil on distillation. Examined under the microscope some of these cannel coals, known as torbanites (named after Torbane-hill) which Mr. Craig has particularly studied, were seen to contain minute globules of oil which had formed gels with the colloidal inorganic matter embedded in the coal matrix. Showing many slides of torbanites, extraordinarily rich in these gels, those from the Transvaal and New South Wales yielding up to 160 gallons of oil per ton, Mr. Craig pointed out that the gels could not be vegetable fossils, as had been supposed by other geologists, since they did not disturb the laminations of the coal, though they had formed across them. At 250 deg. C. these torbanites—cannel coal containing sufficient colloidal inorganic matter which had been subjected to pressure under sealing, in a natural autoclave—and gels gave off light oils, at higher temperature heavier oils; they could therefore not have been formed at high temperatures. The high content (18 per cent.) of inorganic matter in them had quite recently been confirmed by Professor A. E. Flynn in Nova Scotia. Summing up, Mr. Cunningham-Craig suggested that torbanites, oil shale and free oil were often overlying, and also overlapping one another, and that oil shale denoted "petroleum dead and buried" and torbanite denoted petroleum "still-born." With regard to animal origin he said that it seemed difficult to find deposits sufficiently rich in animal matter for experiments, though there must have been such deposits, if there were any truth in the animal origin theory.

The animated and prolonged discussion of the paper reverted to many interesting points, and may be said to have shown at any rate that any decision in favour of the one or the other theory would be premature. Mr. A. W. Nash and Mr. Dewhurst, Dr. A. E. Dunstan, Mr. Madgewick and others had weighty objection. If coal and oil were connected—Mr. Cunningham-Craig pleaded that he only claimed association—why did we have coal in England and no oil, and the opposite in the Punjab, while the main coal and oilfields of America were far apart. Where did the hydrogen come from in the proposed Bergius conversion of vegetable matter, and what became of the nitrogen and phosphorus of animal matter on the other hand? Oil might form in deltas cut off from the sea by barriers; the magnesium chloride might then serve as catalyst as the chlorides of aluminium and zinc did in many laboratory reactions, and it was significant that traces of vanadium—a notable catalyst—were frequent in petroleum. Dr. Dunstan questioned any real similarity between the Bergius oils and petroleum; but he also asked Mr. Craig to give a definition of petroleum. Dr. Dworkowich, speaking on behalf of Professor Zelinsky, of Moscow, also present, referred to the latter's noteworthy distillation of paraffins and other petroleum constituents from the sapropelic deposits (algæ) of Taschkend. There certainly remains a great deal to be done, and we agree with Dr. Spielman that the co-operation of chemists, biologists, bacteriologists and geologists will be required to solve the problems of the origin of petroleum.

FURTHER TURBO-GENERATOR TRIALS AT DALMARNOCK POWER STATION.

IN our issue of August 31, we were able, by the courtesy of Mr. R. B. Mitchell, chief electrical engineer to the Glasgow Corporation, to publish the results of an official test carried out on a Metropolitan Vickers turbo-generator of 18,750 kw. capacity installed in the large power station at Dalmarnock. In the same issue we gave an exhaustive analysis of the performance of the machine, in which it was shown that the multiple exhaust arrangement, which is the particular feature of the design must be highly efficient in itself, and valuable in sustaining the performance of the turbine as a whole. The machine in question is known as No. 3 and, thanks again to Mr. Mitchell, we are now able to publish the test results of No. 2 set, which was also built by the Metropolitan-Vickers Company, Limited, and is a sister plant to the one formerly dealt with. Sectional illustrations of these turbo-generators were given in our issue of April 15, 1921.

The tests on No. 2 set were carried out on September 19 last, the machine having been in commission since August 31, 1920. During this period of over three years it had been on load for 17,908 hours, out of a possible total of 26,737 hours. It was thus actually working for over 67 per cent. of the whole time, during which it generated 204,559,800 kw.-hours. Its average load was therefore 11,421 kw.

During the 26,737 hours that the turbine had been in commission, it was actually available for service for 25,297 hours, or 94·4 per cent. of the whole time, and it could have been running for this period had the conditions of load warranted its use. It must be remembered that the whole period comprises the time since the plant was first put on commercial service, and as the turbine represented a big departure when it was first installed, arrangements were made that it should be opened up and inspected on more than one occasion soon after it was first put into operation. These inspections were arranged, not as a result of any difficulty in running, but as a reasonable precaution to ensure that everything was in order. It would have been possible during the three years, to have found lengthy periods during which the plant was available for service 100 per cent. of the time, but the reliability is best proved by giving the three-years' overall record, as we have done above. In the recent report of the Prime Movers Committee of the American National Electric Light Association, records of reliability are given in respect of 74 large turbine units. The period covered in each case is only twelve months, and does not include the initial period of service. Nevertheless only 13 of the units lost so small a percentage of the possible running time during the year as the Dalmarnock machine has done in its three years' life. The machine thus has a most enviable record, and the results of the tests taken after so long a working period, is conclusive proof that hard work has had no appreciable effect on its efficiency.

The designed steam conditions and the guarantees were identical for No. 2 and No. 3 machines, which were both built to use steam at 250 lb. per square inch, and 650 deg. F., and exhaust to a vacuum of 29·1 in., with the barometer at 30 in. The guaranteed steam consumption per kilowatt-hour, for power measured after the transformers, was 10·44 lb. on an average calculated as follows: Three times the consumption at the maximum continuous rating was to be added to five times the consumption at the most economical rating, and the sum so obtained was to be added to twice the consumption at 75 per cent. of the nominal rating. The total figure so obtained when divided by 10 gives an average over the loads concerned which is "weighted" in accordance with the relative importance of the loads, so that the average represents more fairly the commercial value of the machine than any individual performance. The machines were so designed that the maximum continuous rating and the most economical rating were identical, the consumption in both cases being 10·32 lb. per kilowatt-hour, while at 75 per cent. of this rating the designed consumption was 10·92 lb. per kilowatt-hour.

Table I below gives a summary of the official test on No. 2 machine.

TABLE I.

Date of test	September 19, 1923.		
Nominal load, kilowatts	18,750	15,000	11,250
Average load at alternator terminals, kilowatts	19,000	16,400	12,500
Duration of test, in hours	1·194	1·543	1·178
Pressure at stop valve, pounds per square inch	258·2	257·4	257·0
Temperature at stop valve, deg. F.	712·0	711·0	698·0
Vacuum, inches mercury (Bar = 30 in.)	28·71	28·89	29·02
Actual steam consumption in pounds per kilowatt-hour (power measured at alternator terminals)	9·873	9·745	9·982
Steam consumption corrected to designed condition (power measured at alternator terminals)	9·903	10·00	10·235
Steam consumption corrected to designed conditions (power measured on high-tension side of transformer)	10·00	10·086	10·317
Average consumption, pounds per kilowatt-hour		10·106	

The electrical instruments used were calibrated at the Manchester School of Technology, the thermometers were calibrated at the National Physical Laboratory, and the pressure gauges were calibrated on site by a deadweight tester. The results show that the guaranteed average consumption of 10·44 lb. per kilowatt-hour was easily beaten, the test figure being 10·106 lb. or over 3 per cent. better than the guarantee. The machine, in fact, is seen to have had a slightly higher efficiency than No. 3 set previously tested, and this is consistent with the results deduced from the general station performance. The difference in the two machines is accounted for by a slight difference in the blading. The running blades are identical in the two cases, but in the later machine there were small modifications made in the design of the fixed blading of the high-pressure stages. It will be noted that the actual steam consumption of No. 2 machine at a load of 16,400 kw. was down to the extraordinarily low figure of 9·745 lb. per kilowatt-hour, measured at the alternator terminals. Only a very few years ago a consumption of 10 lb. per kilowatt-hour seemed an almost unattainable ideal, yet the continual perfection of detail has enabled this to be now easily surpassed, and British manufacturers have shown more than ever during recent years that when actual performances are in question, they have nothing to fear from Continental competition.

A striking difference between the test conditions of Nos. 2 and 3 machines is found in the vacuum worked at in the respective cases. No. 3 machine, as will be recollected from our former article, was tested with a vacuum of 29·25 in. at full load and 29·31 in. at a load of 15,650 kw. Such conditions are naturally adverse to the turbine as the volume of the steam is enormously increased at such low pressures, and consequently the velocity through the last stages is considerably greater than is compatible with the efficiency for which the machine was designed. A fraction of an inch of mercury may not seem much to the uninitiated, but the difference in volume between steam at 29·1 in. and 29·31 in. of mercury is more than 23 per cent. The fact that such a vacuum was obtainable is a tribute to the effectiveness of the condensing plant, and the agreement of the makers to a test under such conditions is evidence of their faith in the performance of the machine. Compared with the figures we have given, the full load vacuum of 28·71 in., with which No. 2 machine was tested, is very moderate. It should be borne in mind, however, that the condenser in this case was not cleaned prior to the tests, and was to some extent fouled by the leaves and vegetable matter brought down by the Clyde at this time of the year. The performance of both machines is in every respect creditable, especially after their long service before testing, and both the Metropolitan-Vickers Company and Mr. Mitchell are to be congratulated upon the results.

MODERN METHODS IN RAILWAY CARRIAGE BUILDING.

IN any type of engineering manufacture which involves the machining of metal parts which have ultimately to be fitted together and in which a large number of similar articles have to be made, it is nowadays taken as a matter of course that the various parts shall be machined to jigs and gauges and inspected before passing forward for assembly. In motor car and machine tool building, for example, this procedure is so well established that it probably never occurs to the younger men concerned in the trades that matters could be tackled in any other way. The advantages of a gauging system in eliminating expensive hand fitting, quite apart from any questions of spare parts and replacement, are so obvious that one would expect it would be adopted wherever possible, and as far as the manufacture of metal articles of good class is concerned the method is rapidly becoming universal. There are, however, other branches of work in which the possibilities of improving both output and quality by the adoption of these modern methods hardly appears to have been considered, and the extension of them to the building of railway carriage bodies, which is being carried out by Mr. R. W. Reid, the chief carriage and wagon superintendent

of the London Midland and Scottish Railway at the Derby Works of the company, constitutes pioneer work of very considerable importance.

It is probable that any suggestion for the extension of modern machining methods to wood work, involving machining to size within close limits and inspection with limit gauges, would in general be met by the statement that wood was too unreliable a material for such a procedure to be possible—that the wood would warp or shrink after machining and that assembly without hand fitting would prove impossible. The only reply to this is that experience at Derby shows these fears to be groundless as far at least as the well-seasoned timber used in railway carriage construction is concerned. The timbers mostly used are teak, oak and jarrah, and it has been found that tenons can be machined accurately to size to fit mortises and that parts may be taken indifferently and put together without any necessity whatever for hand fitting or any kind of selective assembly. It is, of course, the usual practice in carriage building to machine tenons to about the right size for the mortises into which they

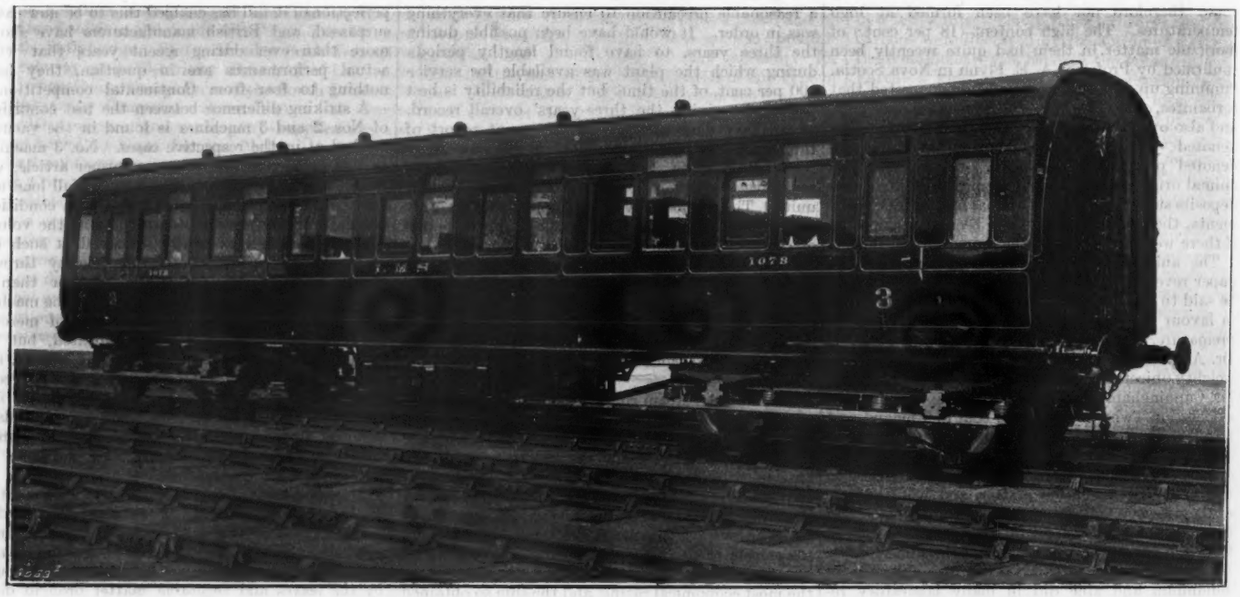


Fig. 9. Third-Class Vestibule Coach: London Midland and Scottish Railway.

are to fit, but it is usual to leave them on the full side to ensure that they shall be large enough, and then for the erector to have to pare them down and adjust the two parts to make them go together. This procedure is both expensive and slow, and experience at Derby shows that it is quite unnecessary. If such parts are machined correctly to size they can be relied on to go together like a wheel goes on a splined shaft, and to give a better job than is attained if local hand-fitting is relied on.

If interchangeable parts are to be produced in quantity direct from machines it is necessary that the machine tools should be suitably arranged for the work. In metal working this presents no difficulty, since capstan lathes and similar repetition tools are built with adjustable stops, scales and other features making them specially suitable for this kind of work. Builders of wood-working machinery have not, however, in the past experienced any demand for similar fitments on their productions, and one of the first things which had to be done at Derby, after it was decided to adopt this interchangeable system on an extensive scale, was to fit the various wood-working machines with various fixed and adjustable stops which would ensure that parts should be turned out duplicates each of the other. A limit of 0·004 is worked to on tenons and similar parts, and it will be evident that only first class wood-working machines in good condition can be relied on to continually turn out work to this accuracy. In view of the standard aimed at the latest and best type of wood-working machinery has been installed and older machines have been scrapped. Incidentally it may be said that the whole of the wood-working shops have been re-organised in connection with this scheme, but we do not propose to deal with that aspect of the subject now in view of the importance of the interchangeable and gauging methods to which we desire to direct attention.

There were two other preliminary matters which had to be dealt with before the system could be put properly into force. The first of these constituted a difficulty which the man used only to good class metal working would probably not anticipate. It lay in the impossibility of buying tools such as square chisels, mortise chains, &c., which were sufficiently accurate to size for the purpose in view. This condition may be explained by the fact that no demand has previously existed for such tools. It has been overcome, and if the methods in use at Derby extend as it is to be hoped they may, such wood-working tools manufactured to close limits will become ordinary articles of commerce. The other preliminary matter had reference to the setting-up of the wood-working machines. In modern tools of this class setting up time normally absorbs a high proportion of the total time required for any job. The setting-up of a four-cutter planing machine might, for instance, take anything up to an hour, and yet with the feeds which are now possible, may run up to 250 ft. a minute, and quite a fair-sized order might be put through in half an hour. In any scheme of repetition manufacture it is clearly undesirable that the setting-up time should bear the proportion to the machinery time which is indicated by this example, and the matter has been dealt with at Derby by overhauling the designs of the various types of carriages with a view to standardising as many detail parts as possible, so that they can be put through in large batches.

As an example of what has been achieved by this overhauling of design, reference may be made to the corridor partitions which before the present methods were put into operation were made in one piece, the first and third-class partitions being different as regards the length of rail, size of panels, &c., the variation being due to difference in size of first and third-class compartments. By splitting up the partition, however, and making it in three parts, two of which are used either for first or third-class compartments, a common piece has been made possible which can be put through in large quantities. Certain of the rails which go to make up the corridor sliding doors have also been made standard with the partitions. The difference in size of compartments is met by making the centre piece of a different width for first or third-class. This example forms an excellent illustration of the way in which a large amount of standardisation of parts has been made possible, and the same method has been followed in connection with other interior fittings of the carriages.

It is not necessary that we should deal in any further detail than we have already done with the machining of the various parts, but we should like to repeat that all parts are gauged and inspected exactly as in the case of motor car engine building. Various slip and other gauges of the "go" and "not-go" types are used. When the machining and gauging systems had been properly developed and were in regular operation, a system of unit assembly was put into operation at Derby. This is a fairly obvious feature of the whole procedure, and consists in the assembly of the partition boards of compartment carriages, doors, door lights, quarters for compartment coaches and other similar items in quantity so that they can be carried in their assembled state and drawn upon as required for erection into complete coaches. The assembly of outside doors is illustrated in Fig. 1, on Plate XXIV. They are assembled on a locating jig which has three compressed air cylinders for squeezing the tenons into the mortises. It may be repeated that the parts go together at once as drawn from stock without any hand-fitting of any kind. While the assembled door is still in the jig and the parts are held well up to the shoulders by the air cylinders, the magazine screw driver, which is carried over the jig, is brought into operation and the screws are driven in. All doors are made to a definite standard, and are fitted in a standard cast-iron door opening.

Other examples of unit assembly are illustrated in Figs. 2 to 4, on Plate XXIV, Fig. 2 showing the assembly of carriage partitions. The magazine screw-driver can cover the whole area of the partition and the whole of the screws are driven without the partition being moved after assembly. The operation of assembling quarters for compartment coaches is shown in Fig. 3. In this case a belt-driven power clamp is used, but the operation in general resembles that of the assembling of doors. As before the screws are driven while the tenons are held right up to the shoulders. The side framing and end frames of carriages are assembled in the same way, an illustration of the operation in an end frame being given in Fig. 4. The side frames after assembly in this way are panelled and moulded, and are finally assembled on the coaches as complete

units. The roof is also assembled and placed on the carriage as a complete unit, but before referring to the details of this operation it will be well to say something about the actual assembly of a complete coach as shown in Figs. 5 to 8, on Plate XXIV.

The first operation in coach assembly is the building of the floor on the underframe. Originally the bogies were removed and the underframe was lowered on to blocks in order that the floor should come at a convenient level for men to work at it. This procedure has now been abandoned, however, and the floor and coach body are assembled on the complete underframe with the bogies in place. This has eliminated the lifting of the coach for the removal and replacement of the bogies, and to enable men to work conveniently on the floor under these conditions a platform has been built alongside the track on which the coaches are erected. This comparatively simple matter is another example of the attention which has been paid to the elimination of unnecessary operations at Derby. The assembly of the floor frame is shown in Fig. 5. The method of procedure is to bolt one bottom side down on to side bars and by means of special clamps to pull the cross-bearers into the middle bearer. The other bottom side is then put on the frame and a special portable cramp which runs along both bottom sides, is brought into use. This clamp is fitted with ball bearings and is very easily rolled up and down to full length of the framing. The clamp is clearly shown in the figure. The hand wheel at each side enables two men to pull the second bottom side on to the cross-members and hold it tight up to the shoulders. The screws are then driven in and the floor boards, which are cut dead to length and require no fitting, are then put in. The approximate time taken to put a floor together is one day of 8 hours.

With all the various parts assembled independently in the way we have described and with the interchangeable system which has been developed, the actual building time of a carriage body has been reduced from six weeks to six days. As a matter of fact, the actual erection time from the completion of the floor to the finishing of putting on of the roof, is under 1 hour. We personally had an opportunity during our visit to the Derby shops, of seeing this building carried out in considerably under 1 hour. The erection during which this remarkable figure is obtained is carried out in two lines of railway laid down in the erecting shop, and each capable of holding two 57-ft. carriages. Each carriage being worked on has a platform built on the shop floor all the way round so that no scaffolding has to be used. The steel underframe on its own bogies is first run on to the erection lines and the floor is laid as described above. The erection gang then puts the ends in place. They are pulled down into the end boards by means of portable compressed air cylinders, which are run under the underframes, special tie rods being fixed at the top of the ends. The air cylinders pull the tenons right home into the mortises practically instantaneously when the air is turned on, the machine work which has previously been done of the parts concerned being such that they go together at once without fitting or humouring. The sides are then erected in a similar manner, but in this case the tenons are pulled into position on to their shoulders by portable racks and levers, which can be seen in Fig. 7. These are moved into different positions by the men operating them, and the side is worked down into its final position in a few minutes.

The next operation is the putting on of the roof, but before dealing with this something must be said about the building-up of the roof, which is assembled as an independent unit in the same way as the sides, ends and other parts we have already dealt with. The roof is built up on a jig at floor level, which is illustrated in Fig. 6. The jig shown in that figure is the one first constructed and consists, as will be seen, of heavy wood blocks secured to the floor. This jig is still in use, but a later model has also been constructed with a metal framework carrying top rails on which cast-iron dummy pillars can be fixed, and which are adjustable to suit the roofs of various classes of coaches. The cant rail is placed on these dummy pillars and the roof sticks, which have previously had their stiffening angles secured to them in a screw-driving machine, are fixed in position. The roof boards are then put on and in this case are screwed down by hand. The roof is a large member to arrange for the service of a screw-driving machine, while the matter is complicated by the fact that the screws have to be driven normally to the curved surface. We understand, however, that the possibility of applying machine screw-driving to the securing of these roof boards has not been lost sight of by Mr. Reid. The roof is then canvassed and painted and the water strip and cornice fixed, and is ready for assembly on the coach.

The completed roof is lifted off the jig by two small hand cranes, which run the full length of the erecting lines. It is then carried above the coach to the position shown in Fig. 8 and dropped on to the top of the ends and sides. It should be said that a series of temporary struts are placed between the bottom ends of some of the roof sticks, while the roof is being built up. These assist it in retaining its shape and are not removed until it is in its final position on the coach. When the roof is resting on the top of the ends and sides and located to the correct position, clamps are applied to the inside of the cant rails, and the whole roof is pulled down home on the shoulders of the tenons of the side framing. This operation illustrates better than any other the remarkable accuracy which is obtained in the shop gauging system, and the remarkable saving in erection time to which the system leads. The roof cant rails have 90 mortises in them, and these have to register with 90 tenons on the side framing, and it is remarkable to see a roof and side frames built up quite independently go together without hitch in a comparatively few minutes. The possibility of carrying out this piece of work demonstrates conclusively not only that modern gauging systems are applicable to good class woodwork, but that their application leads to results which could probably not be achieved in metal at all. After the roof is finally in place, the steel brackets are bolted down and the bottom quarter panels are put in, and the vehicle is then ready to leave the erection road for the casing boards and three-ply covering of the interior of the roof to be put in place. The assembly of the interior finishing of the body follows the general lines we have already indicated. As most of the material concerned is of rectangular design, the machining work concerned is comparatively simple. All gangway doors and corridor sliding doors are glued up and assembled in jigs without any hand work being done on them, in the same way as the other assembled units we have already dealt with.

At the time of our visit to Derby work was being carried out on a series of third-class vestibule coaches of which one is illustrated in Fig. 9, on page 468. These coaches have a very fine appearance, and examination of a finished sample shows that all shoulders are square and well home, and that the workmanship is of the best class. At the present time 70 of these coaches are being put through. A batch of this magnitude allows full advantage to be taken of the repetition system, but as already explained designs have been so modified that a very large proportion of the individual pieces are equally applicable to corridor or compartment stock. At the present time the coaches are being turned out at the rate of four a week, but as will be quite evident this figure in no way represents the possible best of the erection shops. The remarkable times which are obtained will probably always enable the erection shops to keep well ahead of the machine shops. The whole system has now been in operation for about a year and some 150 coaches of various types have been built. In conclusion we must express our thanks to Mr. Reid for giving us an opportunity to see and describe the remarkable work which is being carried out in his shops. We have also to thank Mr. E. J. H. Lemon, divisional carriage and wagon superintendent for conducting us through the shops and explaining the details of this very interesting work.

THE SHIPBUILDING INDUSTRY.

THE combined effects of the slump in shipping freights and the misguided action of the boilermakers are clearly reflected in the present position of the shipbuilding industry in Great Britain and Ireland. For the first quarter of the year a slight improvement was apparent, but this was not maintained during the second quarter, and for the quarter just completed a further decline has to be recorded. From the returns just issued by Lloyd's Register we learn that the tonnage now in hand in British and Irish yards amounts to 1,271,195, as compared with 1,337,759 tons at the end of June, and with 1,617,045 tons a year ago. The decline for the quarter thus amounts to 66,564 tons (5 per cent.), and for the year to 345,850 tons (21½ per cent.). These figures, however, do not accurately represent the present position of the industry, since work has been suspended on some 19 per cent. of the tonnage classed as in hand. The suspended tonnage now approximates to 242,000, so that work is actually proceeding on about 1,029,000 tons only. The latter figure, it should be pointed out, is the lowest recorded for the last 14 years.

As might be expected, the tonnage launched during the quarter just concluded, viz., 66,474 tons, shows a considerable reduction on the figure for the previous quarter, when 239,373 tons were put into the water. Of greater importance from the point of view of the immediate future of the industry, however, is the fact that the new tonnage laid down during the September quarter was less than half that commenced in the June quarter, the figures being 111,860 tons and 241,283 tons respectively.

The vessels now nominally under construction in this country comprise 247 steamers making 1,014,724 tons, 49 motor ships with an aggregate tonnage of 254,426, and 8 sailing vessels or barges, which only account for 2,045 tons between them. It is interesting to note in this connection that, while the steam tonnage under construction has fallen off considerably during the last year, the tonnage of motor ships building has more than doubled in the same period. Motor ships, in fact, now constitute 20 per cent. of the shipbuilding work in hand in this country, and the proportion, we may add, is practically the same for the whole world.

Foreign shipbuilding has also declined during the quarter under review, the total tonnage classed as under construction abroad being 1,106,502, as compared with 1,206,097 tons at the end of June. The difference thus amounts to 99,595 tons, which is a reduction of just over 8 per cent. on the June figure. A certain amount of tonnage in the hands of foreign shipbuilders is suspended, although the proportion is less than that now held up in this country. The work suspended in foreign yards at present amounts to 83,000 tons, or 7½ per cent., and subtracting this from the total work in hand abroad, gives about 1,024,000 as the tonnage upon which work is actually in progress.

The vessels building abroad include 266 steamers, making 884,712 tons, 78 motor ships of 206,442 tons in the aggregate, and 39 sailing ships and barges, which together make up the remainder of 15,348 tons. Germany and Danzig between them account for nearly 30 per cent. of the foreign total (345,985 tons, to be exact), while other important contributions are made by Italy (145,423 tons), France (142,660 tons), Holland (104,491 tons), United States (99,383 tons), Japan (78,012 tons), Denmark (47,305 tons), and the British Dominions (38,445 tons). The Japanese total is, of course, affected by the terrible catastrophe which has befallen that country, but the figure given includes the vessels building at Yokohama on August 15 last. In most countries the work in hand is less than was the case in June; Italy, Holland, Japan and Denmark are the only exceptions in this respect.

The merchant shipping now under construction in the whole world thus comprises 687 vessels, with an aggregate tonnage of 2,377,697, of which 513, making 1,899,436 tons, are steamers; 127, making 460,868 tons, are motor vessels, and 47, making 17,393 tons, are sailing vessels or barges. As previously pointed out, motor ships constitute practically 20 per cent. of the total tonnage building, and we may also mention that vessels intended for the transport of oil in bulk account for another 7½ per cent. Rather more than half of the total tanker tonnage, which amounts to 178,590, including vessels of 1,000 tons and upwards only, is building in this country. With the exception of the

tankers, the figures given refer to vessels of 100 tons and over, and in all cases the tonnages quoted are gross.

NOTES.

Fire Prevention and Extinction.

The Royal Commission on Fire Brigades and Fire Prevention which was appointed at the end of the year 1921, with Sir Perceval Laurence as chairman, presented its report on July 20, and it was recently published by His Majesty's Stationery Office. The terms of reference showed that inquiries were to be conducted into the effectiveness of existing provisions for the avoidance of loss by fire, covering the wide field of building regulations, dangerous processes, the arrangements for research and the furnishing of information to local authorities and also into all matters relating to the control, maintenance, equipment and training of the brigades. A report was to be made on changes thought necessary. In dealing with the questions as they affect factories, workshops and warehouses the Commissioners recommended the provision of means of escape where more than 20 persons are employed or where 10 or more are normally working on any floor above the first. It was also suggested that the Secretary of State should have powers to make general regulations regarding the requirements, and that the local authorities should be given permission to issue certificates specifying the approved systems. It was also proposed that the occupiers of factories should be required to intimate to the local authorities any change increasing the fire risk. Attention was drawn by the Commissioners to the importance of fire drill, the necessity for first-aid fire appliances, and the value of sprinklers and drenchers. Restrictions were proposed on the use of untreated soft wood for match-boarding in buildings when the fire-proofing of timber becomes a commercially practicable proposition. In that field and many others, further research was suggested. The materials used in the construction of railway rolling-stock and on board ship were also the subjects of recommendations. The introduction of motor traction and motor-driven pumps has completely revolutionised the whole system of organisation of fire brigades. The rapid concentration of fire fighting equipment is now a possibility, and in consequence of this arrangements have been made by groups of local authorities for mutual co-operation.

A Measure of the Industrial Depression.

The evidence presented on the 5th and 6th to the Burgh Valuation Appeal Court relating to the claims for reduction of assessments on twelve works belonging to ten of the leading shipbuilders and engineers in the Glasgow area, gives a very good index to the magnitude of the present industrial depression. Similar statements in connection with the steel industry were heard some time ago, and a reduction in assessment of one-third was granted because of stagnation in trade. In evidence on behalf of the appellants, Mr. A. J. Campbell, of Messrs. Wm. Beardmore and Co., Limited, Dalmuir, presented statistics on employment and the use of the shipyard berths. In the twelve works under consideration the average number of men employed in pre-war times was 28,051. In the war period that figure was greatly exceeded and the aggregate of the largest number employed in each works reached 44,801. The present condition, when only 14,482 can be found employment, stands out in very striking contrast. Official statements of unemployment in the shipbuilding trades showed the figure for the whole of Scotland to be 39·4 per cent. In the yards of the members of the Shipbuilding Federation in England and Scotland there are 600 berths; of these, 155 are occupied by work in progress, 56 are taken up with vessels on which the work has had to be suspended, and 389 are vacant. The experience in the different areas, such as the Clyde, for example, showed similar proportions, there being little variation in the conditions in districts. In concluding his evidence, Mr. Campbell referred to the marked increase in the shipbuilding capacity of other countries and the competitive effect it might have on British shipyards. In the five years, 1909 to 1913, the tonnage built in Britain amounted to 7,589,846 tons, of which 22½ per cent. was constructed for foreign owners. Sir Thomas Bell and the representatives of the individual firms gave confirming evidence of the magnitude of the depression. Because of these unhappy conditions in the industry the appellants sought a reduction in their assessments of 33⅓ per cent., but although the court was convinced of the necessity for some relief they decided that it should be limited to 12½ per cent. From the statements made in the course of the appeal the extent of the trouble is manifest, and although a certain resumption of work would immediately follow the cessation of labour troubles, and new construction already ordered or contemplated could be proceeded with, full activity or even a reasonable proportion of it will only be possible when the shipping industry is again prosperous.

LITERATURE.

Flying. By Major W. T. Blake, F.R.G.S., A.M.I.Ae.E. London: George Allen and Unwin, Limited. [Price 6s. net.]

In this book we have the views of the practical airman, whose skill and nerve have taught him all that can be done with the existing forms of flying machine that mathematicians have designed and experiment has perfected. Few can have better qualifications for undertaking the task of describing the pleasures and excitement of flying than Major Blake, who has fifteen years of experience behind him, has tested the capabilities of some 30 types of aircraft, both aeroplanes and sea planes, under various conditions and in many countries. He is admirably fitted to initiate the tyro, to encourage the timid, and to restrain the too eager enthusiast. One does not become a proficient in flying by reading books, but the many hints given here on acquiring the necessary skill and ready resource demanded in piloting an aeroplane, cannot but be useful to the amateur and instructive to those who see in the aeroplane a means for achieving quick and economical transport.

Very good information is given concerning the construction and management of aerodromes, the mooring and garaging of aircraft, and a host of practical matters, but when the author enters the field of prediction we may doubt the accuracy of his forecast, not that we question the reliability of his figures, which indicate large development, or have an alternative scheme to submit, but progress rarely takes the route which seems obviously marked out for it. The engineer, having the opportunity for devising new types of structure, is not likely to be content with merely enlarging existing models and pursuing methods from which the possibilities of originality are excluded. Here he is operating in a medium whose resources have not been adequately explored, with mechanism that does not fully satisfy the physicist or the mathematician. The details of incompleteness are easily perceived, but the remedies are unknown and only dimly conjectured. While this uncertainty exists, it is hazardous to picture the future. Structural forms now little regarded may obtain greater significance, while others, that have acquired undue importance by reason of unusual speed or capacity for rapid ascent, may be superseded. Competition between present methods of transport may force development into unexpected directions.

But the aim of the author here is to indicate what has been achieved, and to demonstrate how past experience can be best utilised, while maintaining a continuous development of the scheme hitherto followed. He has useful chapters showing the value of aeroplanes in providing a means of rapid carriage and in supplementing the services of rail and transport. The point which is hardly sufficiently emphasised is the increase of personal superintendence required in aerial transport. If an airship is utilised the crew is large in comparison to the weight carried, and in aeroplanes the disproportion is still more marked. Under any circumstances, a considerable increase in employees must be contemplated, and his remarks on physical and psychological fitness are much to the point. The sense of responsibility in pilots is a quality that must be fostered, but he must be prepared to accept risks and estimate relative dangers. Foolhardiness—the acceptance of undue risks—is very properly condemned, exhibition flying should not be encouraged, but "stunting," he urges, is an essential part of the training of a first-class pilot. "By looping, rolling, spiralling and gambolling through the sky the airman gets to know his own capabilities and limitations." It is by such means that he learns to use the most efficient manœuvres that may save his passengers when in a dangerous situation.

Other useful chapters have reference to navigating the craft in the air, and the exhibition and detection of adequate signals to guide the pilot on his hazardous path. We think the author is inclined to underrate the care that has been devoted to this subject, and the degree of efficiency obtained. Cloud, fog, and mist at night still present grave difficulties, and though good results may follow the use of the red light of strontium, the plan has hardly passed beyond the experimental stage. The cone lighthouse at Croydon is successful, and under good seeing conditions is visible at a distance of 30 miles. A very satisfactory "flood light" has been installed, which illuminates the whole aerodrome surface, and the scheme of automatic switching is making good progress at several stations. The use to be made of meteorological intelligence is still doubtful and hazardous, and must be, since changes may be rapid and local in character. The most that can be done is to place the pilot in possession of the factors that control the weather over considerable areas, and to train him to incorporate with this general information the modifying facts collected from local sources.

"The Causes and Prevention of Corrosion." By A. A. Pollitt, M.Sc. London: Ernest Benn, Limited. [Price 25s. net.]

The fact that all common metals are liable to corrode has for centuries been taken as an inevitable circumstance, and it is only quite recently that serious attempts have been made to grapple with this age-old problem. That the latter is at any rate partially soluble seems well within the bounds of possibility, and it is to be hoped that the time will come when the world's mineral wealth will be used to the greatest economic advantage. During recent years many papers have been written and reports issued on the causes and prevention of corrosion, but we believe Mr. Pollitt's work to be the first text-book to be entirely devoted to that subject.

In order to limit the scope of his treatise the author states at the outset that the oxidation of metal due to heat alone, such as occurs in furnaces and in metal generally when service involves contact with abnormally hot atmospheres, and the oxidation of the blades on the superheat stages of a turbine, will not be regarded as corrosion. He, therefore, gives the following definition which forms as it were the basis of the work. "Corrosion is a surface phenomenon and consists primarily and essentially of a solution of the metal; or, in the case of an alloy, of one or more of its constituents; through contact with an electrolyte."

Passing on to the factors which bring about the initiation of the corrosion of iron, the author states that the acid theory and the electrolytic theory are the two principal hypotheses held by scientists and adds, that although the supporters of each reach conclusions which are academically opposed, they agree that from a practical point of view the phenomena of corrosion are explained most satisfactorily on an electro-chemical basis. Oxygen is regarded as being essentially the cause of corrosion, and the hastening influence of such factors as variations in the composition of metals, surface impurities, non-metallic inclusions and internal stresses, are thoroughly discussed. Sections dealing with impurities present in waters used for steam-raising purposes, *e.g.*, dissolved gases, calcium and magnesium salts, will be found of vital interest to engineers as they give rise to various types of boiler troubles and to the corrosion of condenser tubes. Remedies are suggested in a well-thought-out chapter on processes of water purification. These have as their object the elimination of scale-forming and corrosive constituents and the "degassing" or removal of the dissolved oxygen and carbonic acid gas present in feed-water.

A chapter devoted to paints, varnishes, and allied

protective coatings will be found very helpful. It is an admirable *resumé* of the whole question. The author states that the ideal of a non-corrodible material has not, at present, been attained although advances have been made in that direction. He therefore devotes some space to the consideration of oxide coatings and metallic and non-metallic protective coverings while admitting that they are not entirely satisfactory.

We would like to suggest that instead of dismissing the subject in the somewhat cursory words quoted above, a brief allusion to modern corrosion-resisting alloys such as "rustless" steel would have proved a useful feature. It cannot be disputed that the extensive research carried out on this latter material has yielded much invaluable information, and has revealed the sterling qualities of what was at first but an imperfectly understood alloy. The main objection to its extended use—its relatively high price, directly due to the high cost of ferro-chrome, will gradually be overcome. It would seem that the real solution of the problem under consideration is to be found in the study of non-corrodible alloys. Mr. Pollitt has nevertheless produced a concise and deeply thought-out work, he has fully grasped present difficulties, and all his suggestions in the direction of amelioration are ably described and well worthy of the consideration of engineers. His treatment of the theoretical side of the subject shows him to be an excellent chemist, and all corrosion reactions and chemical changes are illustrated by means of equations.

BOOKS RECEIVED.

Aeronautical Research Committee. Reports and Memoranda. No. 822. *An Attachment of the Main Balance of 7 Ft. No. 2 Wind Tunnel for Measuring Three Forces and Three Moments.* By T. LAVENDER and others. [Price 3½*d.* post free.] No. 838. *The Mechanics of the Wöhler Rotating Bar Fatigue Test.* By Professor W. MASON, D.Sc. [Price 3½*d.* post free.] No. 844. *A Direction and Velocity Meter for Use in Wind Tunnel Work, &c.* By T. LAVENDER. [Price 3½*d.* post free.] No. 863. *The Effect of a Temperature of 210 Deg. F. on Steel submitted to Alternating Torsion.* By Professor W. MASON, D.Sc. [Price 9½*d.* post free.] No. 866. *Calculation of the Rotary Derivatives due to Yawing for a Monoplane Wing.* By H. GLAUERT. [Price 6½*d.* post free.] No. 867. *The Interference of Wind Channel Walls on the Aerodynamics Characteristics of an Aerofoil.* By H. GLAUERT. [Price 4½*d.* post free.] London: His Majesty's Stationery Office.

Fifteenth Annual Report of the Hydro-Electric Power Commission of the Province of Ontario for the Year ending October 31, 1922. Toronto: Clarkson W. James.

Forschungsarbeiten aus dem Gebiete des Ingenieurwesens No. 262. *Beitrag zur Spannungsuntersuchung an Knotenblechen eiserner Fachwerke.* By Dr. Ing. THEOPHIL WYSS. Berlin: Verlag des Vereines deutscher Ingenieur and Julius Springer.

A First Course in Machine Construction and Drawing. By T. M. NAYLOR and W. TATTERSALL. London: H. F. and C. WITHERBY. [Price 6*s.* net.]

Town Planning and Town Development. By S. D. ADSHEAD. London: Methuen and Co., Limited. [Price 10*s.* net.]

Radio Activity and the Latest Developments in the Study of the Chemical Elements. By K. FAJANS. Translated from the Fourth German edition. By T. S. WHEELER, B.Sc., and W. G. KING. London: Methuen and Co., Limited. [Price 8*s* 6*d.* net.]

Department of Overseas Trade. Report on the Industrial and Commercial Situation of Austria. By O. S. PHILLPOTS. London: His Majesty's Stationery Office. [Price 2*s.* 1*d.* post free.]

Gas Manufacture. By W. B. DAVIDSON, M.A., Ph.D., D.Sc. London: Longmans Green and Co. [Price 21*s.* net.]

The Hydraulic Principles Governing River and Harbour Construction. By CURTIS McD. TOWNSEND. New York; The Macmillan Company; London: Macmillan and Co., Limited. [Price 12*s.* net.]

Aeronautical Research Committee. Reports and Memoranda. No. 783. *Report on the Effects of Overheating and Repeated Meltings of Aluminium.* By Dr. W. ROSENHAIN, F.R.S., and J. D. GROGAN, B.A. [Price 6½*d.* post free.] No. 820. *Stresses in a Stiff-Jointed Polygonal Frame under a System of Parallel Loads.* By A. J. SUTTON PIPPARD, D.Sc. [Price 6½*d.* post free.] No. 821. *On Castigliano's Theorem of Least Work, and the Principle of St. Venant.* By R. V. SOUTHWELL. [Price 9½*d.* post free.] No. 824. *A Method of Calculating the Characteristics of a Tapered Wing.* By H. GLAUERT. [Price 4½*d.* post free.] No. 825. *The Singing of Circular and Streamline Wires.* By E. F. RELF and E. OWER. [Price 3½*d.* post free.] No. 834. *The Handley Page Slotted Wing.* By H. GLAUERT. [Price 6½*d.* post free.] No. 836. *The Manœuvres of Inverted Flight.* By Squadron-Leader R. M. HILL, M.C. [Price 1*s.* 7*d.* post free.] London: His Majesty's Stationery Office.

La Radiotéléphonie. By CARLO TOCHE. Paris: Gauthier-Villars and Cie. [Pri. 10 francs.]

INDUSTRIAL NOTES.

THE shock to the industrial world of the news that 42 men had been imprisoned in the workings of the Redding Colliery, near Falkirk, as a consequence of the recent flooding disaster, was followed nine days later by the startling but welcome information that five of their number had been saved. Hopes of further deliverances were raised and the efforts continued with increased vigour. The story is one of heroic endeavour with all interests fighting in harmony against overwhelming odds. Cut off from communication with the world the survivors sought a high place in the workings above the water level, and in encouraging companionship they kept up their hearts with the certain knowledge that whatever human skill was capable of would be put to service in their discovery and relief. That solid faith was warranted, and there is even yet hopes that others may be saved. While it is surprising to many that men deprived of food and light and subjected to physical hardship could exist for so long as nine days, there are cases on record where that figure was exceeded under similar conditions. There was a colliery disaster in France some years ago, where 13 men survived for 20 days, and one man was brought out alive after 25 days. Modern plant of the most efficient type has been rushed to Redding, and with a team of rescue workers who are unceasing in their endeavours there are still hopes, as stated above, of the saving of some other lives.

The bulletin issued by the Federation of British Industries is to include quarterly a new section dealing with business conditions and forecasting business prospects. This new section was published for the first time in the issue for last Wednesday. It contains a number of curves on trade and finance, and states that since the banks are only able to lend with safety between 40 per cent. and 50 per cent. of their deposits, the relative movements of the advances (amounts lent) and deposits curves indicate that the maximum which the banks can lend under present conditions is being reached. This means that an increase in trade depends on a further fall in prices. Since, however, the placing of orders and replenishment of stocks by merchants is encouraged by a rise in prices and discouraged by a fall, it is impossible to predict any substantial improvement in trade during the coming months, despite the favourable indications of the other curves given in the section referred to. At the moment, monetary conditions appear to be determined by two conflicting policies: (1) The protection of the dollar sterling exchange; and (2) prevention of a further fall in prices in this country. If the former policy prevails, then, in the absence of a rise in prices in America, it must not only necessitate a further fall in prices in this country, but, owing to the effect on the exchange, make it more difficult for foreigners to buy our goods. These straightforward statements by the Federation of British Industries deserve the careful consideration of every member of the industrial and trading community.

According to a statement recently issued by Mr. Philip Gee, 40, King-street, Covent Garden, W.C. 1, the basis of the second part of the miners' claim for a revision of the National Agreement, to which we have repeatedly alluded in these "Notes" in former issues, is that, under its provision, they are not secured a standard of living equivalent to that to which they had attained in June, 1914. The owners' reply to this contention is twofold: First, that the standard of June, 1914, is purely arbitrary, and cannot, in fact, be maintained unless the industry can afford to maintain it; second, that "1914" and "pre-war" are two very different things. The year 1914 was a period of exceptionally good trade and high wages, and there is no reason to suppose, judging by the experience of previous trade cycles, that, even if there had been no war, the conditions of 1914 would have remained unaltered for nine years. In fact, the average weekly wage of all classes of persons in the industry for the ten years 1904 to 1913 inclusive was 29*s.* 9½*d.* At 5·5 shifts per week this is equivalent to 5*s.* 5*d.* a day, or, allowing for the increase in the cost of living, to a daily wage of 9*s.* 4·45*d.* at the present time. The average daily earnings for September and October are, however, estimated to be 10*s.* 8·35*d.*, so that on this basis the miner is actually 14 per cent. better off than he was "pre-war." No allowance is made in this average per shift for free or cheap coal, or for rent allowance. Nor is any account taken of the fact that since 1914 the hours of working underground have been reduced from 8 to 7, thereby seriously affecting output, and more seriously affecting the proportion of fixed charges and oncost that must be borne by each ton of coal raised.

The Executive of the Miners' Federation and representatives of the coalowners, met at a conference of the National Board in London last week-end, to discuss the demands of the federation for a revision of the National Agreement. The following three points were put forward by the federation: (1) Alteration of the ratio of profits to wages; (2) An increase in the minimum rate of wages prescribed by the agreement; and (3) more detailed information as to costs other than wages.

Mr. Evan Williams intimated that the coalowners could not see their way to grant either of the first two requests, and added that if any question of the revision of the wage agreement arose they themselves would have to propose material alterations. As regards the third point, Mr. Williams pointed out that very full information was at present given and that no reasons had been advanced which, in the opinion of the owners' side, went to show that a further subdivision of the items of cost would serve any useful purpose. He said that the owners were prepared to maintain an open mind on this question, and if it could be shown that a further division of the items in question would assist in the working of the agreement, they would be prepared to consider the matter further.

Mr. Stephen Walsh, M.P., in the absence, through illness, of Mr. H. Smith, president of the federation, intimated that the workers' side could not take the reply of the owners as final, and he asked whether they would be prepared to meet the workers' side again for a further discussion of the matter.

It was agreed that a further joint meeting should be held on a date to be arranged later.

Mr. Walsh further asked the owners on behalf of the miners to grant a general holiday in the industry on the first Monday in May in each year, as a "Labour Day."

Mr. Williams stated in reply that it was outside the powers of the Mining Association to deal with a question of this kind, which was one entirely for consideration by the district coalowners' associations.

In the course of a speech which he made in Derby last Friday, Mr. A. Henderson, M.P., called for a national policy in regard to unemployment. The Government plans to deal with unemployment fell far short, he said, of the direct necessities of the situation, and Government would be compelled to grapple with the problem on much more bold and generous lines. Last Monday, Mr. Henderson, speaking at other places in the provinces, said that if the most perfect peace which human ingenuity could devise were secured, we should still have the problem of unemployment. In view of these two conflicting statements, what can the Government be expected to do? Mr. Henderson then spoke of humanising industry, of raiding the reserve funds of the big industrial concerns, the reserve funds to be used for the workpeople, and so forth, all of which appears to carry us little further.

Practically the same arguments are held in other countries. For example, we find in a recent issue of the Brussels journal *L'Echo de la Bourse*, a refutation of a statement made by a Belgian labour leader. According to him, socialism, when it prevails, will not interfere with the individual property of small owners, because this is the fruit of their work and deprivations. It will however, have the right—when it prevails—to confiscate and to distribute among the community all capitalistic property. No indication is given as to the point at which individual property commences and ends. The number of opportunities for holding their tongues which labour leaders miss has always appeared to us somewhat unfortunate.

EXPLOSION IN AN ALTITUDE CHAMBER.—On the afternoon of September 20, a violent explosion followed by fire occurred in the Dynamometer Laboratory of the Bureau of Standards, Washington, D.C., as a result of which one man was killed instantly, three others injured so seriously that they died during the night, and four others seriously burned or cut. The efforts made by the survivors of the staff in rescuing the injured from the furiously burning wreckage and in shutting off the electric circuits and closing valves, minimised the loss of life and property. The explosion occurred in the altitude chamber which is used in testing the performance of aircraft engines under the conditions of low pressure and temperature obtaining at high altitudes. At the time of the accident the room was being used in investigating the performance of an automobile engine at temperatures corresponding to winter operation, using various grades of gasoline. The work was intended to determine the possible increase in gasoline production per barrel of crude oil, with the accompanying conservation of the national resources, by the use of gasoline of lower volatility. The explosion was due to the ignition of an explosive mixture in the chamber. Most of the men were college graduates with experience and skill in research work.

THE "MOTORAILER" WHEEL FOR MOTOR VEHICLES.

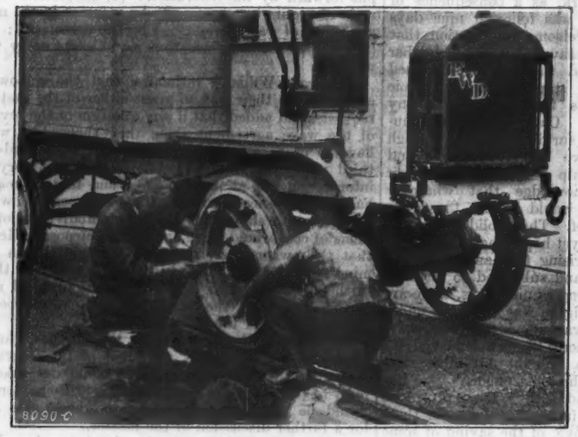
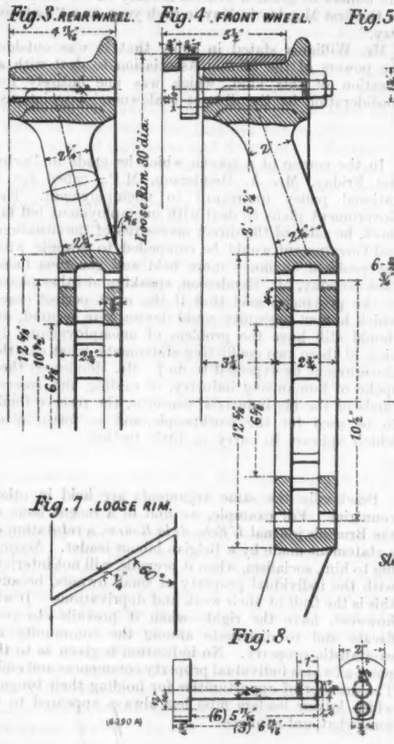


Fig. 1. Converting the Motorailer from the Rail to the Road Form.

Fig. 2. Placing the Motorailer Rim into Position on a Ford Wheel.



The running of motor vehicles on railways has provided a solution for those services where the traffic is so small that profitable working is not possible with ordinary steam trains. Already some forty-two companies are using them in the United States; they operate on six branch lines in England; there are several services in France, Norway, Sweden and Germany, and the system has been tried with success in Australia, South Africa and South America. The advantages that accrue from their use may be greatly augmented if the facility to convert from a road vehicle to a rail one and the reverse, is available. With such a possibility the sphere of usefulness of the system is enormously increased, as the necessity for unloading and loading at the railway is thus removed. To meet these conditions, General Sir H. Capel Holden, Director of Mechanical Transport during the European War, has designed a wheel system known as the "Motorailer," which can be quickly converted from the form required for railway or tram-rail service to that suitable for the road. The device has now been placed upon the market by the Motorailer Transport Company, Limited, of 21, Northumberland-avenue, London, W.C. 2.

In the standard design which is shown in Fig. 1 and the details of which are shown in the drawings Figs. 3 to 8, the motor wheel is of rail track type made of high carbon steel. To convert this into the road form a cast steel rim, with a ½-in. gap cut out of it in the way common with piston rings, is placed around the wheel to provide the requisite horizontal face for the rubber tyre. The rim is held in place by six bolts which pass through the holes at the thickened top ends of the spokes; these bolts have sector-shaped heads (see Fig. 8) which engage in recesses cut into the underside of the rim and are fitted with screwed pins for use in liberating the rim once the nuts are removed. The shafts of the bolt pass through the rim of the wheel and the nuts sit on the inside face.

At a demonstration at Slough on Monday last the system was shown in use on a F.W.D. vehicle. The conversion from road to rail service, including the removal of four tyres and rims and the locking of the steering gear was effected by two mechanics in 8½ minutes total time, while the rims and tyres were replaced and the car put back on the road in 29 minutes. Another design suitable for a Ford of the 1-ton size was also shown in use. In this case the ordinary detachable rim generally used is removed and replaced by a pressed steel rim with one edge turned over to form the flange (Fig. 2). A section of the rim is illustrated in Fig. 9, from which the method of attachment can be clearly seen.

The use of heavily-laden vehicles on roads that are far from perfect was an experience that was common during the European War, and one that is likely to be much in evidence in the conveyance of goods in many parts of the world to-day. A device, called the "Motorlifter," introduced for the purpose of extricating such vehicles from deep mud or sand, and which is manufactured by the same firm, was used extensively for that purpose in transport to all the fronts during the war. It consists of a substantial wooden wedge-shaped block with a metal shoe, and is held to the tyres of the car by chains encircling the rim and sitting in grooves on the block. If a log or other available timber is put in front of the sunken wheel and the engine of the vehicle is then started, the Motorlifter comes on top of the log and further rotation of the wheel causes it to be lifted out of the hole. This simple device thus makes possible the immediate rescue of the vehicle from the mud hole in which it had sunk, and solely by the use of the power given by the engine of the vehicle.

Hydro-Electric Development in New Zealand.—From a statement issued by the Department of Overseas Trade we learn that the City Council of Christchurch, New Zealand, is considering a scheme for the production of electric power from the Waimakariri River at Otarama Gorge. The scheme provides for the supply of energy to Canterbury in place of that now obtained from Lake Coleridge, and the estimated cost of the necessary work amounts to nearly 1,000,000l. The proposals have to be submitted to the Public Works Department for approval before the work can be put in hand, and the Christchurch City Council have therefore drawn up a special Bill styled "The Waimakariri Empowering Bill," which was considered at a recent meeting of the council. A resolution was passed at the meeting urging the Government to expedite the passage of the Bill through Parliament.

CONSERVATION AND CONTROL OF WATER RESOURCES.*

By JOSEPH PARRY, M.Inst.C.E.

THE need has long been felt for a more effective control over the appropriation and distribution of our natural sources of water supply. Every new session of Parliament brings evidence of its increasing urgency. Most of the best upland sources, those with heavy rainfalls, favourable geological conditions, and at elevations suitable for distribution by gravity, have already been appropriated by the big towns. The statutory powers obtained by these municipal authorities and private companies, include possession of considerable areas over which a monopoly has been secured with a view to possible future extensions. These surplus areas are for the most part greatly in excess of the actual present requirements of their owners, and may in fact never be fully utilised. Meanwhile there are many districts badly in want of water, and new demands for both industrial and agricultural purposes are springing up all over the country.

The case was so well stated by the late Sir Harcourt Clare when giving evidence on the Manchester (Haweswater) Bill before a Committee of the House of Commons in the session of 1919, that I cannot do better than quote his words:—

"The broad principle on which the Lancashire County Council have acted is that the natural water supplies to the country at elevations which permit of the water being made available by gravitation for the needs of the population in the lower areas ought to be treated in the character of a national trust, and that Parliament should not authorise the special appropriation of any such supply unless it is satisfied that the best use of it in the general national interest will be made, and that it will be equitably distributed for the benefit of the users who may be considered entitled to share in the supply. . . .

"I go further and say that neither we nor any other authority shall be authorised to appropriate any of the natural water supplies in the Lake District until the Government have taken steps to have a full inquiry made into the whole question of the best methods of dealing with this great national asset. . . .

"At the present moment the situation in the North of England is becoming so seriously pressing that I do suggest that the greatest caution should be exercised in now authorising the appropriation of any natural supply which hitherto has been left untouched until full inquiry into the whole subject has been made . . . . the same inquiry should also, to my mind, extend over the existing water supplies, because I feel sure that if it was enquired into very thoroughly it would be found that far better use could be made of many of these watersheds, that are more or less appropriated to individual corporations or water authorities, than is made at the present time. The water question is getting very serious with the increase of population, not merely to meet the present demands where the water supplies exist but to give what they call a pure supply to a number of areas in the rural districts particularly, who have hitherto been satisfied, or would be bound to be satisfied by very often more or less polluted wells and water collected from the roofs of houses."

Of late years numerous claims have been set up, and authority given, for utilising upland streams to generate electrical energy for industrial works. These are formidable competitors for the sources that are most suitable for water supply purposes. Hence another strong reason for prompt action to lay down principles upon which conflicting claims should be dealt with.

While these claimants for the utilisation of upland catchment areas are pressing their demands there is a considerable and important body of public opinion strongly opposed to any such appropriation in cases, where, by reason of exceptional beauty of scenery or of special historical associations, æsthetic or spiritual values are in danger of destruction by the construction of modern works. A familiar example of this class of opposition occurred in the agitation against the lake schemes promoted by the Manchester Corporation. A similar agitation has been seen this year against the Ceirog Valley scheme of the Warrington Corporation. It is not enough to brush aside such oppositions as being merely sentimental. They deserve a serious hearing, for after all they represent values which are of greater importance to humanity than mere commercial values. Among the inhabitants of the hilly districts affected are to be found the most sturdy members of our race.

Nor is it surface supplies from upland catchment areas that alone call urgently for the attention of Parliament. In the matter of underground sources the conditions are exceedingly unsatisfactory, as was abundantly shown in the Report of the Joint Select Committee on the Water Supplies Protection Bill, 1910. The owner of a well, whether a local authority or a private individual, has no protection against the action of anyone who, by sinking to a greater depth in the same stratification draws away the water and thus renders useless works which may have cost considerable expenditure of money and enterprise. This state of things causes much trouble and loss, especially in the chalk and sandstone areas.

The last Royal Commission appointed specifically to report on national water questions was that of 1867-69, generally referred to as the Duke of Richmond's Commission. It was appointed with very wide powers of inquiry, but the task proved too heavy. Here is an extract from the report:—

"We soon found that such an inquiry must be one of great magnitude, involving a large amount of statistical and topographical investigation extending over the whole kingdom. We felt that it would be impossible for us to undertake this without further powers, while its prosecution would delay, probably for some years, the more important and pressing question as to the Metropolitan supply. For this reason we resolved to complete our report on the latter subject, and to limit our recommendations on the former one to a few general principles."

The investigation, thus somewhat pusillanimously shirked, has never been resumed. Branches of the subject have been considered by Commissions, such as those on the pollution of rivers and fisheries, but there has been no attempt to grapple with the subject as a whole and to formulate recommendations as a basis for legislative enactments. The law on the subject is sadly out of date. The principal Act—the Water Works Clauses Act—was passed in 1847, and an Amendment Act in 1863. Great changes have since taken place; new knowledge has been acquired, new conditions have been established, new demands have arisen. All these matters have to be taken into account in any effective revision of the law.

In the various recommendations which have been made with regard to needed reforms in water administration, stress has been laid on two points, a survey and control. It is important to distinguish between these—between an inquiry into the water resources of the country on the one hand and the adoption of a national system of control and distribution on the other.

The urgent need of a comprehensive survey is shown by the rapid manner in which the best upland sources are being taken possession of by the great industrial centres, by the alternative schemes so often set up before Private Bill Committees, also by the projects now being brought forward for power schemes which involve the construction of catchment reservoirs. To carry out a complete survey is undoubtedly a big task. It should include not only engineering facts as to areas and levels but also geological facts as to suitability of sites for reservoirs, rainfall returns, chemical and medical reports on quality, particulars of population affected and character of soil in the several areas, actual yield and use of any areas already appropriated, also suitability of direct river supplies at low levels by pumping.

These are matters of fact to be ascertained by qualified experts and should be published for the public benefit. It is understood that much of the desired information is already in the possession of Government departments. I refer specially to information collected by the Geological Branch of the Ordnance Department as to the resources of water yielding rocks. The completion and tabulation of the survey should be pushed on without further loss of time.

The determination of a national policy to be adopted and of new legislative provisions required need not be postponed until the whole of these facts have been recorded. To find a comprehensive foundation for such a policy a Royal Commission would, in my opinion, be the best preparation. For the ascertainment of facts a Government department may suffice, but for laying down principles on which legislation affecting the whole country is to be founded a higher authority is required. Such a Royal Commission, with its public sittings, would attract the attention of the country and would elicit the views of public authorities and professional men interested, thus providing an adequate foundation for recommendations to Parliament.

The Departmental Committee appointed by the President of the Board of Trade have, in their second interim report, supplied much useful information and made a number of valuable suggestions, but their recommendations do not command the authority of a Royal Commission of the kind I suggest, nor do they by any means satisfy the requirements of the case. What they recommend is, in effect, the setting up of a new and very costly Government department with very arbitrary powers of control over all water resources and waterworks and with the task imposed upon them of solving all the difficult problems of water supply. Bad as the present unsatisfactory method of procedure by private Bill Committees may be, the alternative proposed would be still worse. We certainly do not want any extension of bureaucracy, and Parliament is not at all likely to adopt a scheme that has any such tendency.

In the Appendix to the Interim Report reference is made to a paper which I contributed to the Society of Arts Congress in 1878 recommending that the principal watersheds should be adopted as the administrative areas on water supply questions. The authority I then contemplated was an unpaid representative body, appointed by all the local authorities in each watershed, with a central Committee formed of representatives from the several watersheds—a very different body from the Water Commission proposed in the Interim Report.

The Royal Commission on Salmon Fisheries, 1902, in expressing approval of a recommendation of the Royal Commission on Sewage Disposal, say, "It might even be possible to create a Watersheds Board of still larger authority. There are three great subjects for all of which, in our opinion, the watershed is the proper administrative area, i.e., pollution, water supplies and fisheries." (Page 12, Report.) The ideas of centralisation which prevailed even so late as the beginning of the present century differed greatly from those which are now advocated in official quarters.

One advantage of a Watershed Authority would be that supplies to rural areas would necessarily receive more consideration than they have done. Hitherto public attention has been almost exclusively devoted to town supplies, while the needs of villages and farmsteads have been sadly overlooked. Polluted wells and streams still abound, causing much ill-health not only to the rural population directly affected but also, indirectly, to the urban populations through their consumption of milk and other country produce.

I have referred to the objections raised on æsthetic and humanitarian grounds to the submergence of certain valleys by the construction of reservoirs. Such cases will probably be more frequent in the future than they have been in the past, and it may be useful if I point out how the interference complained of may be in most instances avoided.

What the promoters of schemes for water supplies really want is the water which flows in the rivers through these upland valleys, and what the opponents usually object to is inundation of the valleys by the building of reservoirs. I want to point out that there is a way by which these hostile forces may often be reconciled. The chief reasons for providing storage at the place where the water is abstracted are, the cheapness of the land, favourable geological conditions and the delivery of compensation water. Now there are plenty of examples of the necessary storage reservoirs being built near to the point of delivery and not at the point of abstraction, but perhaps I can most clearly explain the position by reference to a case recently before Parliament.

In the session of 1921 the Corporation of Preston applied for powers to take an additional supply of water direct from certain tributaries of the River Hodder—a drainage area of 4,729 acres. The Bill was strongly opposed on the ground that a catchment reservoir should be built in the valley so as to provide for a steady delivery of compensation water, but the promoters contended that the geological conditions were unsuitable for reservoir construction. The Private Bill Committee after a full hearing granted the powers applied for by Preston (subject to an alteration as regards quantities), and thus confirmed the principle that in appropriate circumstances a supply may be taken direct from an upland stream. The works necessary for diverting a portion of a river are simple and unobtrusive. The pipes for conveying the diverted water to its destination are hidden under the surface of the ground. A further consideration in support of storage works being built near to the town where the water is to be used, is the facility thus afforded for employing local labour instead of sending gangs of navvies into temporary camps in remote upland areas.

The Royal Commission of 1869 made one important contribution to the national water question by recommending: "That when any town or district is supplied by a line or conduit from a distance provision ought to be made for the supply of all places along such line." But there was no recommendation as to the terms on which the supplies should be given. The first attempt to specify terms of payment was made in the Manchester (Thirlmere) Act, 1879. The arrangement was found to be so unsatisfactory in practice that the subject was reopened when the Haweswater (Manchester), Scheme came before Parliament in 1919. Amended terms were then enacted, after long discussions, but in practice they will prove to be equally unsatisfactory and far more complicated. It is avowedly a difficult matter to legislate for.

Under existing circumstances, and in the absence of any general scheme of distribution, the most satisfactory arrangement in practice would appear to be that conditions of supply should be left subject to agreement between the parties directly cocerned, and, failing agreement, to be settled by arbitration. In the case of Liverpool, voluntary agreements for supplies in bulk have been entered into with 56 local authorities and private individuals along the lines of aqueduct. Statutory powers should, however, be given to county councils to arrange for such supplies on behalf of areas within their jurisdiction. Deficient and polluted supplies are very common in rural areas through the neglect of local authorities to enforce the powers they posess, and the county councils under the advice of their medical officers should be authorised to act in such cases and made responsible for the provision and distribution of wholesome water.

Prominent among the subjects calling for consideration by a Royal Commission are (*a*) The quality for water to be distributed for domestic purposes in the light of recent investigations, notably those of Sir Alexander Houston; (*b*) the amounts and method of delivery of compensation water to rivers; (*c*) the rights of rivers and fishing boards to exact penalties for failures to deliver prescribed quantities of compensation; (*d*) the desirability of substituting filtered river water as compensation instead of water from unpolluted sources (as in a recent Sheffield case); (*e*) an amendment of the law as to flowing surface water; and (*f*) amendment of the law as to underground supplies.

* A paper read before Section G of the British Association at Liverpool, September 17, 1923.

THE DEVELOPMENT OF THE SINGLE-BUCKET EXCAVATOR.*

By W. BARNES, M.I.Mech.E.

THE earliest excavating machines recorded were introduced for removing material from below water level. Illustrations and descriptions of these can be traced back over 300 years, but land excavators are of comparatively recent introduction, and it is the purpose of this paper to deal only with these.

Most of the under-water excavators, and a few land machines, are of the dredger or endless bucket type, but this paper confines itself to the single-bucket excavator, commonly known as the steam navvy or steam shovel, and the still more recently introduced excavator known as the drag-line.

The first steam navvy was designed by William Otis, of Boston, U.S.A., in 1839, and built by John Souther of the same city, see Fig. 1, page 474. It was a very crude machine compared with those of to-day, but the fundamental principles of our present-day steam navvies were embodied in its construction. The excavating gear consisted of a

* A paper read before Section G of the British Association at Liverpool, September 17, 1923.

THE DEVELOPMENT OF THE SINGLE-BUCKET EXCAVATOR.

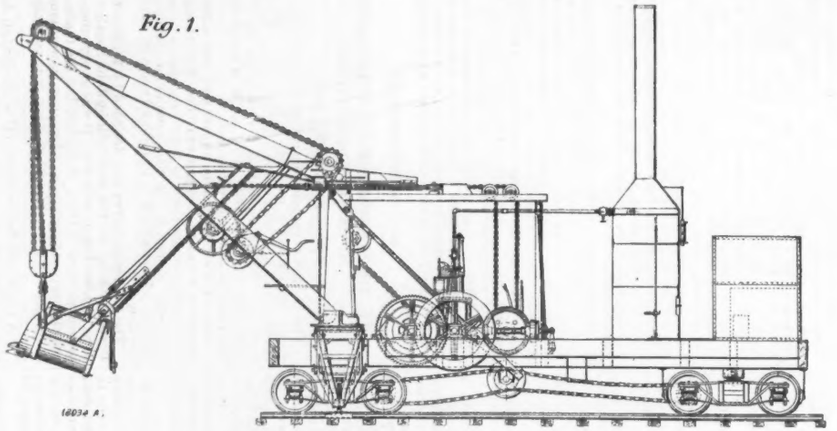


Fig. 1. Otis Steam Navvy of 1839.

Fig. 2. Dunbar and Ruston Steam Navvy of 1875.

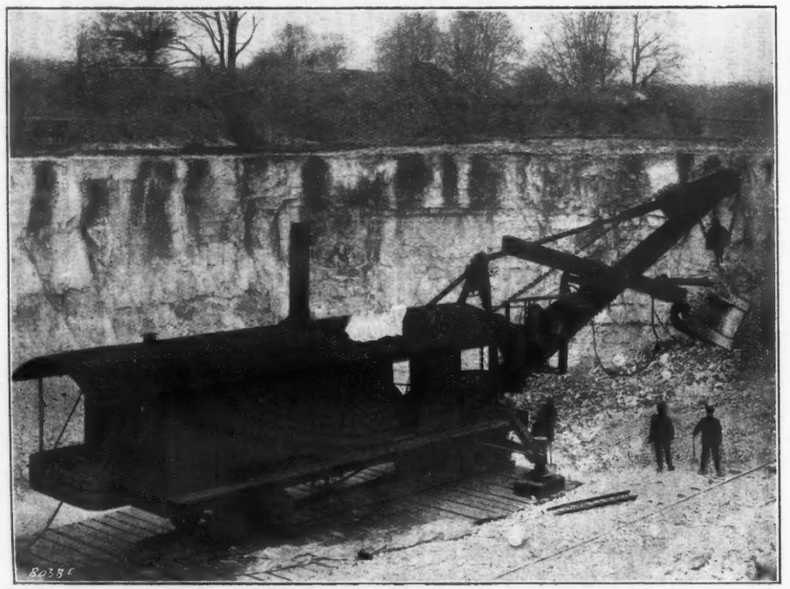


Fig. 3. Modern Steam Navvy of the Limited Swing Type.

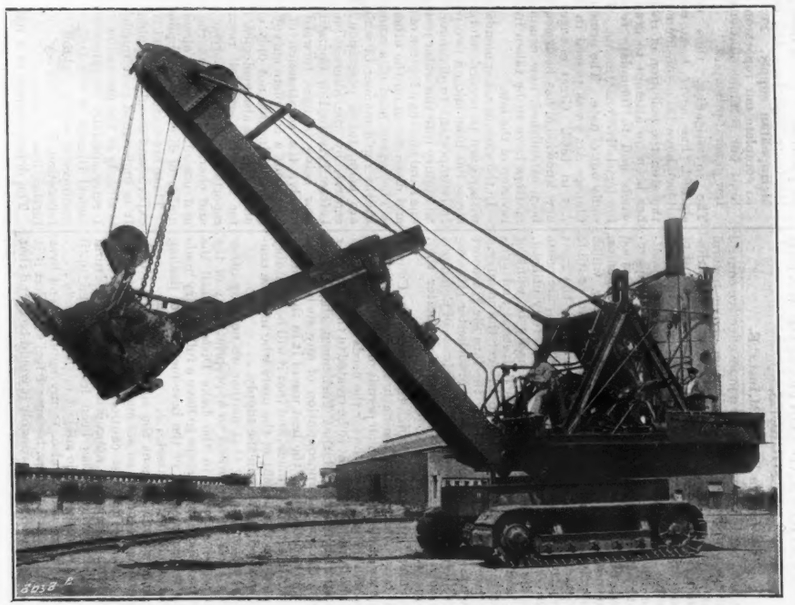


Fig. 4. 80-Ton Steam Crane Navvy (Full Circle Type).

DEVELOPMENT OF THE SINGLE-BUCKET EXCAVATOR.

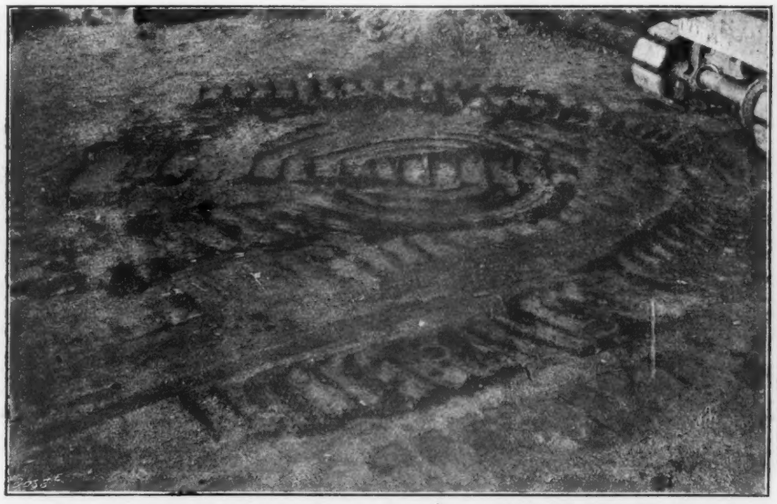


FIG. 5. TURNING TRACK OF A CATERPILLAR-FITTED TRACTOR.

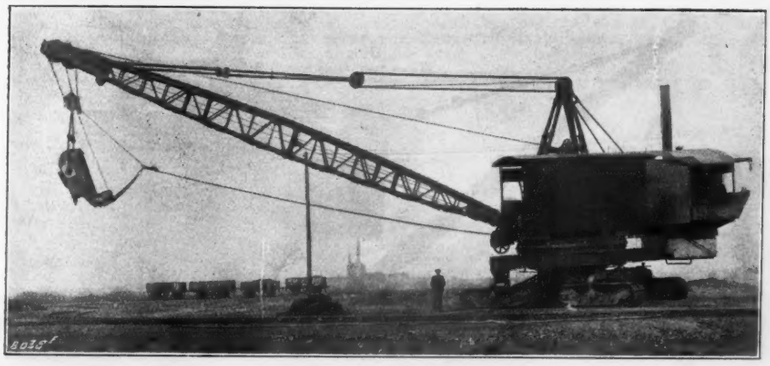


FIG. 6. 90-TON DRAGLINE EXCAVATOR MOUNTED ON CATERPILLAR TRACKS.

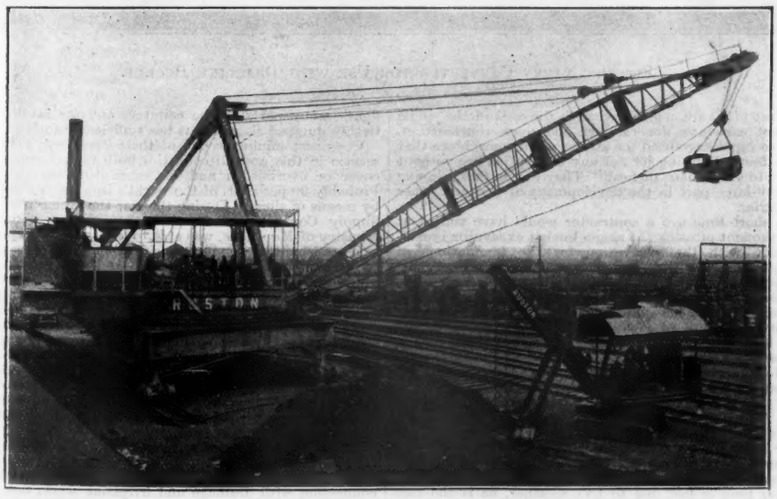


FIG. 7. 300-TON DRAGLINE EXCAVATOR.

jib carrying a bucket on the end of an adjustable radial arm. The digging power was communicated to the bucket by means of a chain leading from the main drum over a pulley at the end of the jib, and the bucket was constructed with an adjustable tie from the bucket to the bucket arm to enable the dip or angle to be varied to suit the material which had to be dealt with. Teeth were also fitted to the cutting edge, and the contents of the bucket were discharged by means of a door fulcrumed at a point forward of the door itself, so that it (the door) mechanically closed and relatched itself, when it was lowered preparatory to taking another cut. Means were also provided for racking the bucket in and out at the point of suspension to vary its cutting and discharging radius. All these movements are included in modern excavators, considerably elaborated and improved of course, and instead of one engine being employed for driving all the motions, as on the Otis and some later machines, three sets of engines are usually fitted, in addition to auxiliary engines and steam cylinders for operating the various clutches, &c.

The Dunbar and Ruston Steam Navvy.—The next machine, Fig. 2, was the Dunbar and Ruston steam navvy, introduced by Ruston, Proctor and Co., of Lincoln in 1875. Fundamentally, it was similar to the Otis, but of much sounder design and construction. Mild steel plates and angles were extensively adopted in place of the timber so largely used in the Otis. It was employed in the construction of the Manchester Ship Canal, over 70 of them being used in the excavation of this important waterway. A proof of the sound construction of the old Dunbar and Ruston machines is found in the fact that some of these machines, over forty years old, are still at work.

In modern machines of the Otis and Dunbar and Ruston types, in which the excavating gear only swings through 180 deg., the triangulated jib has been superseded by a crane jib (see Fig. 3) supported by tie rods to an "A" framing or legs of the derrick pattern, all carefully designed so that the resulting stresses in the jib ties, "A" legs and back tension stays, meet at a common point at the top of the "A" framing.

The width of the framing is such that the machine will clear reasonably wide and high railway loading gauges, with the jib and "A" frame lowered, and travel on standard rail gauges from 3 ft. 6 in. to 5 ft. 6 in. wide. For this purpose bogies, as used on ordinary railroad rolling stock, together with jacks on outriggers, are fitted to give the necessary stability when the machine is digging across the framing, and more or less at right angles to the centre line of the machine. Three sets of double cylinder engines are used—one set for hauling the bucket up the face or in other words digging—another set for swinging the bucket out of the face for discharging the excavated material, and a third set for racking the bucket in and out as required to regulate the thickness of cut taken by the bucket when cutting up the face. In addition, the friction clutch for operating the bucket is controlled by means of a steam cylinder. All these improvements, while adding many additional details, considerably increase the speed, controllability and efficiency of the machine. It is possible, in fact, for present-day machines to make three to four cuts or complete cycles of operations per minute, with a favourable size of machine under good working conditions.

A cycle of operations comprises cutting up the face, adjusting the thickness of cut necessary to fill the bucket at the finish of the cut and yet at the same time avoid stalling the engines, slewing the excavating gear out of the face to discharge the excavated material either into wagons or on to a dump; unlatching the bucket door to release the contents; swinging the jib and bucket back to the working face again and lowering the bucket in readiness for the succeeding cut. It can therefore be seen how necessary it is that every movement should be under easy and perfect control.

Steam Crane Navvy.—The more recent developments in the single bucket excavator have been with the *full circle* excavator or crane navvy, as it is called. The actual excavating gear is practically identical with the machines described, but it is designed to revolve through a complete circle instead of only the half circle. The first machine of this type was constructed by Whitaker and Sons, contractors, of Leeds, in 1887, by attaching excavating gear to an ordinary crane. Like the early Otis machine, it was comparatively crude and only one set of engines was employed for all the motions. A modern machine, as illustrated in Fig. 4, has three engines for the separate motions of digging, slewing and racking, as already described, together with a steam operated friction clutch. It has been still further improved by the addition of the now well-known caterpillar travelling gear, made so popular during the war by its use on the tanks.

This particular machine weighs approximately 80 tons, and a few years ago the idea of mounting a machine of this size and weight on self-laying tracks would have been ridiculed; they are, however, a proved success, so much so that approximately 80 per cent. of present-day machines are being fitted with them. Each track, like those on the tanks, can be separately driven, which makes it possible to turn or steer the machine in a comparatively small space. (See Fig. 5.)

The advantages of caterpillars are as follows:—

(1) Less labour is required around the machine, as they avoid the necessity of having to level the ground and relay sleepers and rails in front of the machine when it is necessary to travel ahead.

(2) A larger output is obtainable as the time lost in travelling ahead is practically negligible—in other words, in place of the 5 to 12 minutes necessary to travel ahead when rails and sleepers are used, the excavator can move forward in almost as many seconds. This is particularly valuable when the working face is shallow and it may be necessary to move ahead three or four times in the course of an hour. Twenty to thirty per cent. of the working time may thus be lost.

(3) The machine can be more readily and quickly travelled from one part of the work to another when occasion requires.

The machines we have so far been considering have been of the steam navvy or steam shovel type. Their main principles are: they cut upwards or above the level on which they stand, take a radial cut away from the machine and travel forward for another series of cuts after the bucket has cut all the material within reach.

Dragline Excavators.—Another single bucket excavator has recently been developed (Fig. 6), in which these movements are reversed—the cut is taken below the

FIG. 3. MODERN STEAM NAVVY OF THE LIMITED SWING TYPE.

FIG. 4. 80-TON STEAM CRANE NAVVY (FULL CIRCLE TYPE).

level of the machine, the cutting action is towards the machine and it travels backwards for another series of cuts. Such a machine is called a dragline excavator, the bucket being dragged towards the machine by means of a rope or line. The development of this machine can be traced from the horse-drawn plough, a scoop being used in place of the plough-share and known as a drag-scraper. The horse-drawn drag-scraper is the cheapest and simplest form of power excavator and is still used in some countries, particularly America and Canada, for road making and shallow excavation.

In 1904, Mr. J. W. Page, an American, used a scoop or drag-scraper in conjunction with a steam derrick. It was a decided success, so much so that the designer and the excavator manufacturers, seeing its possibilities, not only improved the design of the scoop, but designed a special form of full circle excavator to operate it. It is exceedingly useful for drainage or irrigation works where water is present and it is desired to take out material from below the surface of the water, or for cutting an irrigation channel and discharging the excavated material on the surface to form banks. The machinery portion of the machine is very similar to that of the crane navvy, excepting that the racking gear upon the jib is not required and a second hoisting drum is added. The line or rope from the hoisting drum passes over the jib head and is used for lifting the bucket out of the excavation after the cut is completed, also for regulating the thickness of cut taken by the bucket.

The jib, too, is constructed very much lighter and longer, due to the fact that no digging stresses come upon it. In a crane navvy jib, the rope for digging is carried over the jib head to the bucket; consequently, the jib has to withstand the full load together with the digging stresses on the bucket arm. In a dragline, the digging rope is led to the bucket by means of pulleys situated at the foot of the jib, which has only to carry the weight of the bucket and material plus certain slewing stresses.

It can readily be seen how useful the long jib makes the machine for cutting canals and dealing with shallow excavation, as much wider cuts can be obtained.

The following is the sequence of operations:—the bucket is lowered into the excavation at the extreme working radius and dragged towards the machine by the drag rope When the end of the cut is reached, the bucket is lifted out of the cut by the hoisting line and slewed or swung round over the dumping point, the contents being discharged by holding the bucket up on the hoisting line and slacking off the dragline. The front of the bucket being heavier and not held by the combined hoisting and drag ropes, swings forward and downwards and the excavated contents are discharged from the open mouth of the bucket, not through a door at the back, as with a steam navvy.

The latest and largest dragline, illustrated in Fig. 7, has a net weight of approximately 300 tons. It has a jib 120 ft. long and a bucket of 8 cub. yards capacity. These can, however, be varied to suit any particular working conditions; for instance, a 10 cub. yard bucket can be used in conjunction with a jib 100 ft. long, or a 5 cub. yard bucket with a jib 160 ft. long. The upper revolving framing upon which the main machinery is mounted is so large and contains so many power units that it can well be termed a power station.

Three sets of double cylinder engines are mounted upon it, one of 300 h.p. for digging and travelling, another of 200 h.p. for slewing, and a small set for hoisting the coal into the large capacity coal bunker. In addition, two steam cylinders are fitted for operating the hoist and drag drums and two steam operated brakes for controlling the free drag and hoist drums. The boiler is of the locomotive type, weighing 17 tons, with a grate area of 48 sq. ft. The huge size of the machine can also be gauged from the turntable or slewing path upon which the whole of the upper structure revolves, this being 30 ft. diameter. In spite of the large weight and overall dimensions of the excavator, it is so fast in working and so controllable that a complete cycle of operations can be carried out in from 50 to 60 seconds; in other words, 8 cub. yards of material can be dug and dumped about 200 ft. away from the place where it was excavated in less than one minute.

The machine is supported upon bogies at the four corners, the travelling power being transmitted through the centre of the machine on to all four wheels of each bogie, 16 wheels in all. Its power and stability is such that a load of 25 tons can be safely lifted at a radius of 125 ft. A few years ago such large machines would have been considered impracticable propositions. They are, however, so useful on account of their large outreach and outputs, that they are becoming increasingly popular for many classes of work.

Another striking development in the full circle excavator is its adaptability to meet various working conditions and classes of work. A few years ago it was only possible to obtain the crane navvy with the regulation bucket on its radial arm (Fig. 8) and fitted with rail travelling wheels, whereas most of the present-day machines are readily convertible for use with either navvy or dragline equipment (see Fig 9). Further than that, the smaller machines up to about 40 tons in weight can be used in conjunction with the well-known grab type of bucket, as shown in Fig. 10, or even as a locomotive crane. This is very valuable from the general contractor's point of view, as it enables him to work more efficiently with less plant. Another advantage is that when a contract is finished, the contractor has a better chance of obtaining work for his plant with its more universal application. Even the large 300 ton dragline previously described is convertible to a steam navvy with a 6 cub. yard bucket, and jib 90 ft. long.

In addition to the above, caterpillar travelling gear can be used as an alternative to rail wheels on machines up to 120 tons net weight.

DEVELOPMENT OF THE SINGLE-BUCKET EXCAVATOR.

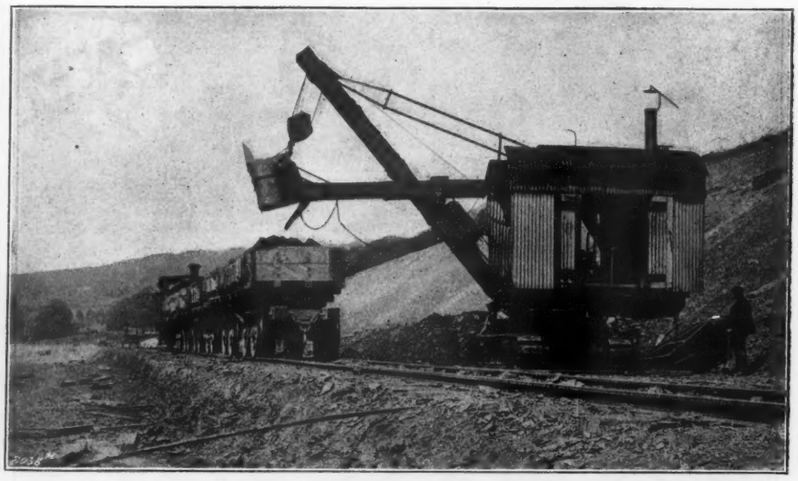


Fig. 8. Steam Navvy Fitted with usual Bucket and Arm.

Fig. 9. Navvy Converted for Use with Dragline Bucket.

Most of us are acquainted with the uses of the single bucket excavator for railroad and dock construction, but so rapid have been the strides of these machines that very few excavating jobs of any description are without them in some shape or form. They are, in fact, playing a very large part in the development of this and other countries.

A short time ago a contractor would have smiled at the thought of using the single bucket excavator in connection with the excavation for the foundations of buildings. Now they are in very common use for this purpose, especially in America, where they are sometimes used to remove only a few hundred cubic yards of material. They have also been a comparatively common sight in London on excavations for foundations during the last three or four years. An example of this is shown in Fig. 11.

Most of the large brick companies in this and other countries are using these machines for excavating their clay, their use having more than quadrupled during the last few years. In addition to reducing the excavation costs below those of hand labour, a better mixing of the clay is obtained owing to the fact that the bucket takes a thin cut the full depth of the face. Further, less time is lost in the clayhole and consequently in the factory, as no time is lost due to bad weather, as is the case when hand labour is used for getting the clay.

Practically all the cement companies in this country use the steam navvy for excavating the clay, chalk and limestone used in the manufacture of cement; in fact, it is probable that 95 per cent. of these raw materials are obtained in this manner. Quite a number are in use for grading work on the new arterial roads. Their use is also being extended to the limestone, granite and basalt quarries for obtaining material to make the new roads and repair the existing ones. Others are in use for excavating slag both from the slag banks which disfigure many parts of the country, and for loading up freshly dumped slag after it has sufficiently cooled.

Open-cast mining is one of their very large fields of service in this and all countries both for removing the cover or overburden and for excavating the mineral. Probably 90 per cent. of the world's iron ore is obtained by means of them. During the war the Home Iron Ore Supply Committee, working in conjunction with the Ministry of Munitions, was able to increase the output of iron ore from this country considerably with fewer men, by granting facilities to purchase and encouraging the use of steam navvies during the very trying period when every effort had to be made to keep up the supply of munitions and while decreasing the imports of foreign ore with the object of relieving our shipping. Unfortunately, we have no coal deposits near to the surface in this country, but they are being largely used in America both for removing the cover and excavating coal. Australia is also using them to excavate the huge deposit of brown coal, some 200 ft. thick, at Morwell in connection with the large power development scheme for Victoria. Copper ore is also being extensively obtained by their means in America, Spain and the Belgian Congo.

The dragline excavator is being extensively used in connection with drainage and irrigation work, not only for cutting new canals and channels, but for cleaning out existing ones. At one end of the scale we get the small dragline excavator weighing about 20 tons, and fitted with a ¾ cub. yard bucket for use in the small drains, which may only be a few feet wide. At the opposite end we have the huge 300-ton dragline excavator, previously described, which has just been delivered to cut the large canals, some of them 200 to 300 ft. wide, in connection with the irrigation schemes in India—the largest in the world and of which the India Public Works Department may be justly proud. It is interesting to note

DEVELOPMENT OF THE SINGLE-BUCKET EXCAVATOR.

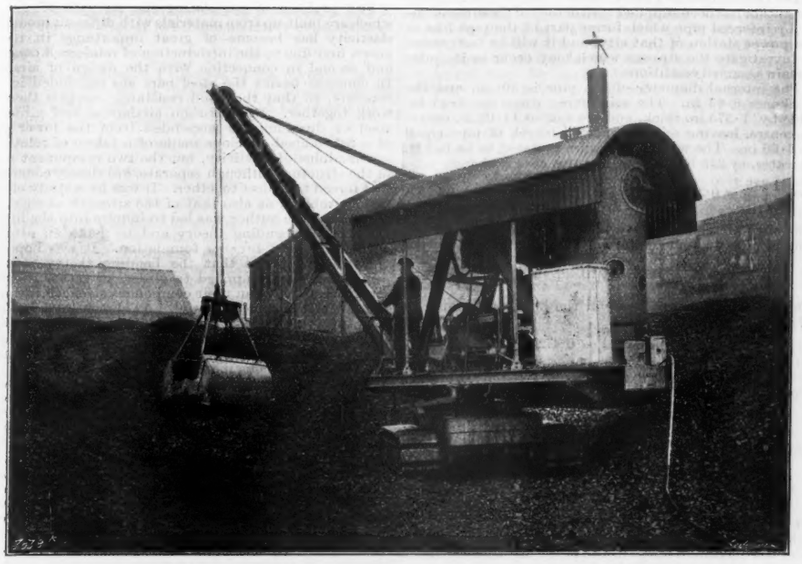


FIG. 10. NAVVY CONVERTED FOR USE WITH GRAB BUCKET.

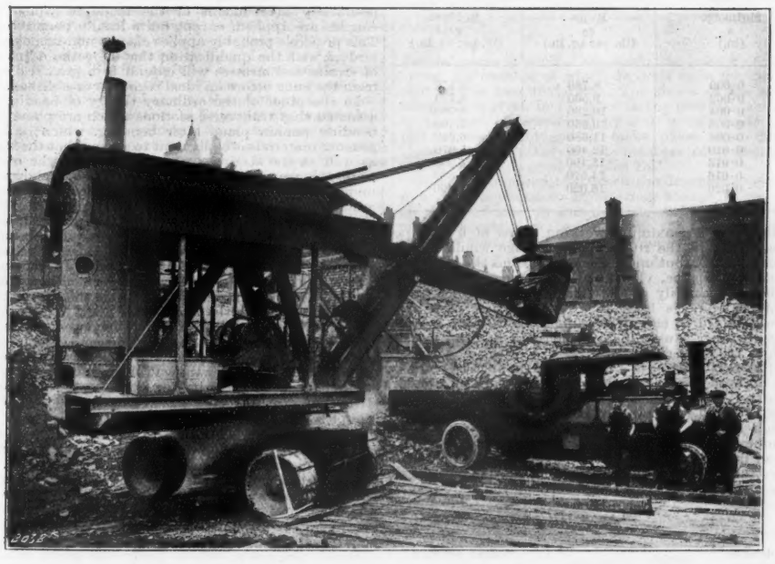


FIG. 11. SINGLE BUCKET EXCAVATOR FITTED WITH WIDE-TREAD WHEELS.

that about 20 dragline excavators are in use upon the irrigation scheme in the Sudan, and it is an excellent proof of the usefulness and efficiency of these machines to know they can satisfactorily compete with the cheap coolie labour in India and the Sudan. In addition, however, to excavating the material at a cheaper rate, they enable the works to be completed and put into profit-earning at a much earlier period than if they were carried out by hand labour alone.

These few examples go to prove the growing usefulness of the single bucket excavator in an ever-widening field in this and other countries and illustrate the very rapid strides made by these machines in recent years.

THE STRESSES IN PIPES REINFORCED BY STEEL RINGS.*

By Professor GILBERT COOK, D.Sc., King's College, London.

IN a contribution to the Report of this Committee for 1921, the author has given the results of a theoretical and experimental investigation of the influence of a flange on the stress distribution in a pipe under internal pressure. The close agreement between the calculated and observed stresses proved the method of analysis to be adequate for the purpose, and may justify its application to the analogous problem of the reinforced steel pipe.

In large hydro-electric installations working under high heads, the design of the pipe line presents considerable difficulties. For a given discharge and head at the power station, considerable economy in material is effected by increasing the size and reducing the number of the pipes, but in a plain welded pipe a limit is imposed to the size by the maximum thickness which can be satisfactorily welded, which may be taken to be about 1½ in. A type of construction recently introduced whereby large diameters may be used for high heads without an excessive pipe thickness consists in reinforcing the pipe by means of steel rings shrunk on at intervals along the pipe. The author has not been able to discover any published account of the method by which the strength of such pipes may be estimated. The construction is protected by patents, and the proprietors have not disclosed the method of arriving at the proportions of the pipe and rings, or the stresses anticipated or allowed for. The investigation which follows has several points of interest, amongst these being the question as to the conditions under which a reinforced pipe may be made lighter than a plain pipe even when no difficulties of welding would be encountered. It also leads to some unexpected conclusions regarding the relation between the spacing of the rings and their effectiveness.

It was shown in the previous paper that the radial displacement at any point of the pipe wall is given by the equation

$$\frac{E m^2}{m^2 - 1} \cdot \frac{t^3}{12} \cdot \frac{d^4 z}{dx^4} + \frac{E t z}{R^2} = P$$

where R is the mean radius of pipe, t the thickness, P the internal pressure, E Young's modulus, $\frac{1}{m}$ Poisson's ratio, and z the radial displacement at any point x measured along the axis from some fixed origin, the longitudinal stress being assumed zero. The solution of the equation is

$$z = \cos nx\,(A \cosh nx + B \sinh nx) + \sin nx\,(C \cosh nx + D \sinh nx) + \frac{P R^2}{E t} \quad . \quad (1)$$

where $n = \sqrt[4]{\frac{3}{t^2 R^2} \cdot \frac{m^2 - 1}{m^2}} = \frac{1{\cdot}285}{\sqrt{tR}}$ if $\frac{1}{m}$ for steel be taken as 0·3. If l be the length of the pipe between successive rings (Fig. 1) and x be measured from A as

Fig. 1.

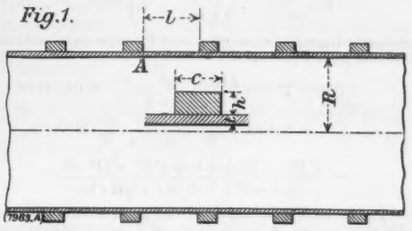
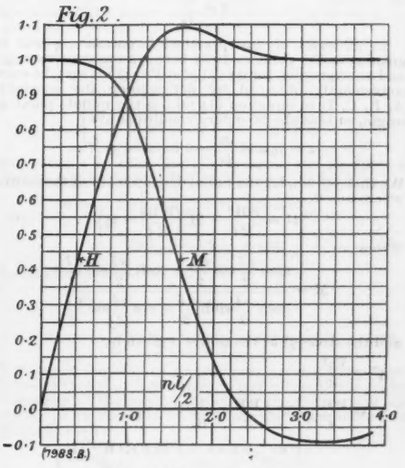


Fig. 2.



origin, then assuming that the pipe wall remains cylindrical under each ring and

$$\frac{dz}{dx} = 0 \text{ for } x = 0 \text{ and } x = l$$

and

$$z = z_0 \text{ for } x = 0 \text{ and } x = l$$

where z_0 is the radial displacement at the ring. Evaluating the constants A, B, C, D equation (1) becomes

$$z = \frac{PR^2}{Et} - \left(\frac{PR^2}{Et} - z_0\right)(\cosh nx \cos nx - H \sinh nx \cos nx + H \cosh nx \sin nx - L \sinh nx \sin nx) \quad . \quad . \quad . \quad . \quad (2)$$

where

$$H = \frac{\cosh nl - \cos nl}{\sinh nl + \sin nl}, \quad L = \frac{\sinh nl - \sin nl}{\sinh nl + \sin nl}$$

In determining the radial displacement at the ring it will simplify the work if, as will always be the case in practice, the radial thickness h of the ring is small compared with R, and the small error involved in taking R to be the radius of the ring be neglected.

Considering the portion of the pipe in contact with the ring, the forces acting upon it in the radial direction will be (1) the internal pressure; (2) the external pressure produced by the ring; and (3) the shearing force across the pipe wall at each side of the ring. Denoting by p the pressure per unit area exerted by the ring on the pipe, and by F the shearing force per unit length of the

* Contribution to the Report of the Committee of Section G of the British Association on Complex Stress Distributions in Engineering Materials, Liverpool, September 18, 1923.

circumference, the equivalent pressure tending to increase the radius will be

$$P - p + \frac{2F}{c}$$

c being the width of the ring, and therefore

$$z_0 = \frac{R^2}{Et}\left(P - p + \frac{2F}{c}\right) \quad . \quad . \quad (3)$$

The value of p depends on the amount of shrinkage allowed in fitting the rings, and on the radial displacement z_0. Let s be the shrinkage, *i.e.*, the amount by which the radius of the ring is less than that of the pipe when both are in the unstressed state. Then the actual stress in the ring is

$$\frac{E(s + z_0)}{R}$$

and

$$p = \frac{E(s + z_0)h}{R^2} \quad . \quad . \quad . \quad (4)$$

Again, applying the method described in the previous paper to the determination of the shearing force F, we have

$$F = -\frac{E m^2}{m^2 - 1} \cdot \frac{t^3}{12} \cdot \frac{d^3 z}{dx^3}$$

which from equation (2) leads to

$$F = \frac{E m^2}{m^2 - 1} \cdot \frac{t^3}{3}\left(\frac{PR^2}{Et} - z_0\right) H n^3 \quad . \quad (5)$$

Substituting the values of p and F given by equations (4) and (5) in equation (3), we obtain

$$z_0 = \frac{PR^2 - Esh + \frac{2R^2}{c} \cdot \frac{m^2}{m^2 - 1} \cdot \frac{t^3}{3} \cdot PR^2 \cdot H n^3}{E(t + h) + \frac{2R^2}{c} \cdot \frac{Em^2}{m^2 - 1} \cdot \frac{t^3}{3} \cdot H n^3}$$

$$= \frac{cPR^2 - cEsh + 1{\cdot}55\,PR^2\sqrt{tR} \cdot H}{cE(t + h) + 1{\cdot}55\,Et\sqrt{tR} \cdot H}.$$

The radial displacement z at any point is then obtained by substitution in equation (2), and the circumferential stress

$$q = \frac{Ez}{R}$$

In all cases of any practical importance, q will be greatest at the point midway between consecutive rings, and an expression for its value at this point may be more conveniently obtained by determining the constants A, B, C, D in equation (1) taking the middle point as origin, so that the boundary conditions are

$$z = z_0 \text{ and } \frac{dz}{dx} = 0 \text{ for } x = \pm\frac{l}{2}.$$

We then obtain, for the radial displacement at the centre, where $x = 0$

$$z^1 = \frac{PR^2}{Et} - M\left(\frac{PR^2}{Et} - z_0\right) \quad . \quad . \quad (6)$$

where

$$M = \frac{\sinh\frac{nl}{2}\cos\frac{nl}{2} + \cosh\frac{nl}{2}\sin\frac{nl}{2}}{\cosh\frac{nl}{2}\sinh\frac{nl}{2} + \cos\frac{nl}{2}\sin\frac{nl}{2}}$$

and the stress q^1 at the centre is given by

$$q^1 = \frac{Ez^1}{R}$$

$$= \frac{PR}{t} - M\left\{\frac{PR}{t} - \frac{1}{R} \cdot \frac{cPR^2 - cEsh + 1{\cdot}55\,PR^2H\sqrt{tR}}{c(t + h) + 1{\cdot}55\,tH\sqrt{tR}}\right\}$$

$$= \frac{PR}{t} - \frac{McH}{c(t + h) + 1{\cdot}55\,HtR\sqrt{tR}}\left(\frac{PR}{t} + \frac{Es}{R}\right) \quad (7)$$

The values of M and H are plotted in Fig. 2 on a base of $\frac{nl}{2}$. Given the radius R and thickness t of the pipe, and the distance apart l of the rings,

$$\frac{nl}{2} = 0{\cdot}642\,\frac{l}{\sqrt{tR}},$$

the values of M and H may be read off from Fig. 2, and the maximum stress q^1 can be readily obtained from equation (7).

The stress that would be produced in a pipe of the same dimensions without reinforcing rings is equal to $\frac{PR}{t}$, and it would appear, therefore, in order that the rings should have any strengthening effect, that M must have a positive value greater than zero. It will be seen from Fig. 2 that this is only the case when $\frac{nl}{2}$ is less than $2{\cdot}36$, or $l < 3{\cdot}66\sqrt{tR}$

This limiting length is independent of the amount of shrinkage given to the rings. When l is greater than $3{\cdot}66\sqrt{tR}$ and less than $8{\cdot}5\sqrt{tR}$, M has a negative value, and the tensile circumferential stress is greater than would occur in a plain tube of the same thickness. It will further be seen from equation (7) that under these conditions an increase in the shrinkage allowance results in an increase in the tensile stress between the rings. Evidence of a similar effect was clearly shown by the experiments described in the previous paper, the stresses being increased by a constraint which would, at first sight, be expected to reduce them.

Through the courtesy of the Chief Electrical Engineer to the Department of Public Service, City of Los Angeles, the author has been supplied with details of the dimensions of a reinforced pipe which forms part of the pipe line to the power station of that city, and it will be instructive to investigate the stresses which may occur in it under certain assumed conditions.

The internal diameter of the pipe is 80 in., and the thickness 0·63 in. The reinforcing rings are 4·45 in. wide by 1·575 in. thick, and are spaced 11·05 in. centre to centre, leaving an unsupported length of pipe equal to 6·60 in. The working pressure is stated to be 642 ft. of water, or 278 lb. sq. in. For this case we have

$$n = \frac{1{\cdot}285}{\sqrt{tR}} = 0{\cdot}255,\ \frac{nl}{2} = 0{\cdot}841,\ H = 0{\cdot}800,\ M = 0{\cdot}925$$

The circumferential stress which would be produced in a similar pipe without reinforcing rings would be

$$\frac{PR}{t} = 17900 \text{ lb. sq. in.}$$

The actual maximum stress in the pipe, from equation (7) is

$$q^1 = 0{\cdot}528\,\frac{PR}{t} - 0{\cdot}472\,\frac{Es}{R}$$

The stress q_0 in the ring is most readily obtained from equation (6) thus

$$z_0 = \frac{PR^2}{Et} + \frac{1}{M}\left(z^1 - \frac{PR^2}{Et}\right)$$

and

$$q_0 = \frac{E(s + z_0)}{R} = 0{\cdot}490\left(\frac{PR}{t} + \frac{Es}{R}\right)$$

The author has no information regarding the amount of shrinkage allowed for the rings. The manner in which, according to this theory, the stress in the rings and the maximum stress in the pipe vary with the initial shrinkage, is shown in Table I.

Table I.

Initial Shrinkage s (in.)	Stress in Rings q_0 (lb. per sq. in.)	Maximum Stress in Pipe q^1 (lb. per sq. in.)
0·000	8,780	9,450
0·002	9,500	8,750
0·004	10,230	8,060
0·006	10,950	7,360
0·008	11,680	6,670
0·010	12,400	5,970
0·013	13,490	4,930
0·016	14,570	3,880
0·020	16,020	2,490

Assuming a maximum working stress of 6 tons per square inch in the rings, the shrinkage would require to be 0·013 in., but under these conditions the maximum stress in the pipe, viz., 4,930 lb. sq. in. would appear to be unnecessarily small. The weight per foot of the reinforced pipe is 1,090 lb. The thickness of a plain pipe designed to carry the same pressure with a stress of 6 tons per square inch would be 0·842 in., and its weight 722 lb. per foot.

If a working stress of 6 tons per square inch be assumed for both the pipe and the rings, the working pressure may be 408 lb. sq. in., and the shrinkage necessary 0·0014 in. To sustain this pressure a plain pipe would weigh 1,059 lb. per foot, which is still lighter than the reinforced pipe. It is, of course, evident that for a given maximum stress and pressure a plain pipe must have the advantage in weight owing to the fact that the stress is uniformly distributed through the material.

Table II.

Distance between Rings (clear). l (in.)	Initial Shrinkage required. s (in.)	Working Pressure P (lb. per sq. in.)	Weight per Foot. Reinforced Pipe. (lb.)	Weight per Foot. Plain Pipe. (lb.)
3·0	0·0122	720	1,350	1,890
5·0	0·0131	628	1,180	1,645
6·6	0·0145	541	1,085	1,410
9·0	0·0187	448	988	1,170
12·0	0·0258	345	905	896
18·5	0·0394	209	800	536
25·1	0·0425	175	740	450
43·0	0·0395	209	595	536

The possibility of allowing a higher working stress in the rings than would be safe for the pipe does, however, enable a reinforced pipe to be made lighter than a plain pipe provided that the rings are sufficiently close together. This is shown by Table II, which gives the results of a calculation based on the dimensions of the Los Angeles pipe, assuming a stress of 10 tons per square inch for the rings and 6 tons per square inch for the pipe. In this table the pressure and the initial shrinkage required to produce these stresses are given for various distances apart of the rings, and the weights per foot of the reinforced pipe and a plain pipe to carry the same pressure with a stress of 6 tons sq. in. It will be seen that the spacing of the rings must be less than 12 in. in order to obtain a lighter pipe.

THE THEORY OF BENDING.*

By Professor William Hovgaard, Member.

The problem of calculating the strength of girders which are built up from materials with different moduli of elasticity has become of great importance in recent years, first due to the introduction of reinforced concrete and second in connection with the design of airships. In concrete beams the steel bars are embedded in the concrete, so that the bond resistance compels them to work together. In semi-rigid airships a keel girder of steel or duralumin is suspended from the lower part of a fish-shaped envelope made of a fabric of relatively low modulus of elasticity, but the two component parts of the structure although separate, are closely connected and forced to deflect together. It was by a study of the latter problem, as also that of the strength of rigid airships, that the author was led to inquire into the limitations of the bending theory and to make an attempt to place it on a broader foundation. It was hoped in this way to prove that the bending theory may be safely and simply applied to girders of rather irregular structure, even when their component strength members are not of the same material. As shown in the following, the investigation led to what is believed to be a new and fundamental proof of the essential soundness of the theory, justifying moreover its extension to beams of non-homogeneous materials.

It is generally conceded that if a beam is homogeneous and perfectly elastic, the ordinary bending theory applies to the case of simple bending even when the transverse sections vary, provided they vary in a continuous manner and not too abruptly. In practice, bending is almost invariably associated with and produced by shearing, but still the theory is used to find the bending stresses, in general regardless of the way in which the bending moment is applied. In most cases the shearing stresses may be calculated independently and compounded with the bending stresses without great error. Strictly it is assumed in the bending theory that the bending is produced by tractions distributed over the terminal sections of the beam in a particular manner, but, as shown by Saint-Venant, when the length of a beam is large compared with its transverse dimensions, the state of stress and strain created by terminal couples is practically independent of the mode in which these couples are applied, except quite locally near the ends. This principle probably applies also to non-homogeneous girders, with the qualification that here the adjustment of strains and stresses will extend to a greater distance from the ends before an ideal régime is established.

In the proof of the ordinary theory of bending it is assumed that transverse sections which are plane before bending remain plane after bending, which in homogeneous materials is equivalent to saying that the stresses as well as the strains are proportional to the distance from the neutral axis. Saint-Venant has shown that under certain suppositions this assumption is justified as an approximation to the first order for beams of homogeneous materials,† but for non-homogenous materials it is not known to have been established theoretically, although it is generally accepted for beams of reinforced concrete on the basis of experiments. In the present paper it is attempted to show that for non-homogeneous as well as for homogeneous materials the assumption is in accordance with the Principle of Least Work; thereby the theory is placed on a simple incontrovertible basis and it is rendered more easy to discern its limitations. If this solution is accepted, the difficulty of the abovementioned "Saint-Venant's Problem" disappears, since there is then no necessity for assuming a particular distribution of the forces which constitute the terminal couples.‡

Consider a horizontal fairly slender beam in equilibrium under the action of terminal forces which produce a uniform bending moment in the vertical plane. The forces acting at the ends are so adjusted as to produce no body forces and no shear except very near the ends. An elemental transverse disc of the beam is enclosed between two transverse sections at a small distance apart. On the elements of area of each section act normal stresses p, which under the given conditions have no axial resultant, but form a resisting couple which balances the bending moment. The distribution of the stresses is supposed to be unknown, and no assumption is made a *priori* as to the existence or location of a neutral axis. The modulus of elasticity may vary in any manner between contiguous longitudinal filaments of the disc.

It is now argued that the stresses and strains must tend to adjust themselves so as to conform to the Principle of Least Work, and in Appendix I this principle is applied to the problem with the aid of the Calculus of Variations. The result obtained is that under ideal conditions, where the strains and stresses have had an opportunity to adjust themselves outside the disc in such a way that the elastic potential is a minimum in the disc, the strains, but not necessarily the stresses, must be proportional to the distance from the neutral

* A paper read at the Summer Meeting of the Institution of Naval Architects, held in Holland, September 5, 1923.

† *Elasticité des Corps Solides.* Clebsch, 1883. Note by Saint-Venant, pages 181–90.

‡ "Ainsi, la formule de la flexion *égale*, ou en arc de cercle, n'est fournie par l'analyse qu'autant que les deux *couples fléchissants* soient formés de forces appliquées normalement sur les bases de la tige fléchie, et distribuées, quant aux intensités, d'une manière linéaire, c'est-à-dire proportionnellement aux distances de leurs points d'application à une même droite. *Op. cit.*, p. 175.

axis. The formula for bending then takes the form :—

$$\frac{p}{y} = \frac{M}{\mu I} \quad . \quad . \quad . \quad . \quad (1)$$

where μ is the ratio between the modulus of elasticity E_0, of a certain material adopted as a standard, and E_1 that of the material of the filament under consideration. Thus $\mu = \frac{E_0}{E_1}$.

In the calculation of I the area of the material, which has the modulus E_1, is divided by μ. In other words, the moment of inertia is calculated to the standard of the material of modulus E_0.

Equation (1) may be written : $\frac{p}{E_1 y} = \frac{M}{E_0 I} = C$

where C is a constant.

If the strain is called e, we obtain

$$e = C y \quad . \quad . \quad . \quad . \quad (1')$$

expressing that the *strain* is proportional to the distance from the neutral axis, while according to the standard formula the *stress* is proportional to that distance, being applicable only to homogeneous materials.

In Appendix I the proof of this theory is given, and in subsequent appendices its application to airships and reinforced concrete beams is briefly discussed.

It is hoped that this paper will elicit comments and criticisms of mathematicians, so that limitations and shortcomings in the theory, not realised or stated by the author, may be pointed out.

APPENDIX I.

THE THEORY OF BENDING AND THE PRINCIPLE OF LEAST WORK.

A girder or beam of any cross-section is subject to a uniform bending moment under the action of terminal couples. No body forces or shear are acting in the part of the beam which we consider, but near the ends, where the couples are applied, there may be shear as in the axle of a carriage.

The material is perfectly elastic and no discontinuities are met with when passing along the Z-axis from one section to another, although the sections may gradually change form. On the other hand, the form of the sections may be quite unsymmetrical, the girder may be constructed of longitudinal members of different moduli of elasticity, and these members, although intimately connected with one another, may otherwise have the appearance of being separate girders and may be arranged in any way over the section.

Referring to Fig. 1, consider a disc of small length enclosed between two transverse section. The plane of one of the sections is chosen as the plane of X Y, and is regarded as vertical, and O X is drawn horizontally parallel to one of the principal axes and tangent to the lowest point of the section, which point is here arbitrarily chosen as origin. The axis of Z is parallel to the line of centroids, and the vertical plane Y Z is the plane of bending, so that the axis of the bending couple is parallel to one of the principal axes. By supposition there are no tangential tractions on the sections ; all the stresses p are normal, and it follows that there are no horizontal tractions between the longitudinal filaments. On the other hand, it is assumed that adjacent filaments or members are so interconnected that there can be no slip between them, a fact which is of importance outside the region of pure bending here considered. The distribution of the normal stresses is supposed to be unknown, but from the given conditions of loading it follows that they produce a couple equal and opposite to the bending moment M, and that they leave no resultant free force.

The contour of the cross-section is a closed curve defined by the equation $x = \phi(y)$, where ϕ is a known and invariable function. Since p may vary, not only with changes in y but also with changes in x, we write :— $p = \psi(x\ y)$ where ψ is the function to be determined. Let y_1 denote the extreme upper ordinate of the section, y_2 the lower, which is here incidentally made zero. We have then the following relations : For horizontal equilibrium the resultant force must be equal to zero :—

$$P = \int_0^{y1}\int_{-x2}^{x1} p\, dx\, dy = 0 \quad . \quad . \quad (1)$$

The bending moment in the vertical plane is :—

$$M = \int_0^{y1}\int_{-x2}^{x1} p\, y\, dx\, dy \quad . \quad . \quad (2)$$

The bending moment in the horizontal plane is assumed to be zero :—

$$M_H = \int_0^{y1}\int_{-x2}^{x1} p\, x\, dx\, dy = 0 \quad . \quad (3)$$

In these integrals the limits denoted by x_1 and $-x_2$ stand for $\phi(y)_1$ and $\phi(y)_2$, that is, they represent the contour values of x for any given value of y.

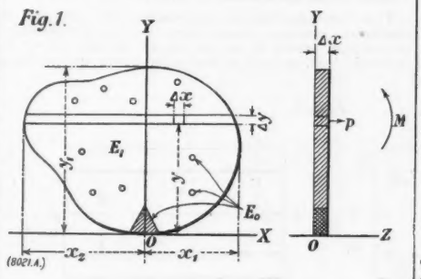
In Fig. 1 and in the following formulæ it is assumed that the disc consists of two different materials, referred to in the following as (0) and (1), having the moduli of elasticity E_0 and E_1, but as shown below, the result applies also in cases where there are more than two different materials. The materials are here for the sake of generality assumed to be distributed in a scattered, although quite definite, manner. Let the length of the element, Δz, be equal to unity. The stresses in the two materials, p_0 and p_1, are expressed by $p_0 = \psi_0(x, y)$ and $p_1 = \psi_1(x, y)$. The elastic work done in elongation and contraction is then :—

$$W = \int_0^{y1}\int_{-x2}^{x1} \tfrac{1}{2}\frac{p_0^2}{E_0}\, dx\, dy + \int_0^{y1}\int_{-x2}^{-x1} \tfrac{1}{2}\frac{p_1^2}{E_1} \quad . \quad . \quad (4)$$

It is here assumed that the lateral contractions and expansions of the filaments, accompanying the longitudinal strains and hence the anticlastic deformations, take place without any expenditure of work. In other words, it is supposed that no transverse stress-forces act on the filaments, each of which behaves as if it were isolated from neighbouring filaments. This assumption has been shown by Saint-Venant in the reference given above to be correct to the first order in slender beams of homogeneous materials, but can be accepted only as an approximation for materials in which Poisson's ratio differs. This, however, will have no significance in a structure as a semi-rigid airship, nor will it influence the result materially for a concrete beam. Consider, for instance, the reinforcing steel bars on the side of compression in a concrete beam. The lateral expansion of the steel being at least one-fourth of the longitudinal strain, while that of the concrete may be only one-tenth, transverse stress forces will indeed arise which do a certain amount of work. In that case equation (4), as it stands, is not strictly correct, as it does not represent the total elastic work, but since the modulus of elasticity of concrete is only about one-fifteenth of that of steel, the error will not be great. Moreover, the term to be added to (4) can, under reasonable assumptions, be brought on the same form as the first integral, of which it will always be a small fraction and with which it can be merged. Thus the form of the function ψ, as determined below, will be the same.

Each of the integrals in equation (4) actually represents the sum of a number of integrals, each of which covers

Fig. 1.



a certain area or zone of the section bounded by a closed curve, the contour of which depends upon the distribution of the two materials. The limits of the double integrals as given in (4) refer to the external boundary of the section determined by $x = \phi(y)$, inside which this piecemeal integration takes place. The first of these integrals takes in all members of modulus E_0, the second all those of modulus E_1.

It is now required that when the dependent variables p_0 and p_1 vary, due to an arbitrary change in the form of the functions ψ_0 and ψ_1, the work, W, shall be a minimum, while at the same time the force P and the bending moments M and M_H remain constant. This condition is fulfilled when $W + a M + b M_H + c P$ is a minimum, where a b, and c are constants, for in that case :—

$$\delta W + a\,\delta M + b\,\delta M_H + c\,\delta P = 0$$

and then, since δp_0 and δp_1 are entirely arbitrary and independent of x and y, the quantities δM, δM_H and δP must all of them vanish at the same time as δW. It will be observed that because M_H and P are zero, it does not follow that δM_H and δP are zero.

Let :

$$U = W + a M + b M_H + c P$$

$$= \int_0^{y1}\int_{-x2}^{x1} \left(\frac{p_0^2}{2 E_0} + a p_0 y + b p_0 x + c p_0\right) dx\, dy$$

$$+ \int_0^{y1}\int_{-x2}^{x1} \left(\frac{p_1^2}{2 E_1} + a p_1 y + b p_1 x + c p_1\right) dx\, dy \quad (5)$$

It is required then that the variation of U shall be zero when p_0 and p_1 are made to vary independently by a small amount, not due to a variation in x or y, but due to a variation in the form of the function ψ. By the rules of the Calculus of Variations it is found that :—

$$\delta U = \int_0^{y1}\int_{-x2}^{x1} \left(\frac{p_0}{E_0} + a y + b x + c\right) \delta p_0\, dx\, dy$$

$$+ \int_0^{y1}\int_{-x2}^{x1} \left(\frac{p_1}{E_1} + a y + b x + c\right) \delta p_1\, dx\, dy = 0 \quad (6)$$

In these equations p_0 and p_1 are dependent variables, which we shall first assume to be entirely independent of each other. The variations δp_0 and δp_1 are in that case quite arbitrary, whence it is necessary, in order that δU may certainly vanish for any such variations, that each of the two integrals in (5) shall vanish. In order that this shall happen, we must have :

$$\left.\begin{aligned} \frac{p_0}{E_0} + a y + b x + c &= 0 \\ \frac{p_1}{E_1} + a y + b x + c &= 0 \end{aligned}\right\} \quad . \quad . \quad (7)$$

Actually p_0 and p_1 are not at all points independent of each other, since the strains at the boundaries of the two materials are supposed to be everywhere the same. Hence we have the equation of condition :

$$\frac{p_0}{E_0} = \frac{p_1}{E_1} \text{ or } f(p_0, p_1) = p_0 E_1 - p_1 E_0 = 0$$

which must hold at all points of the section where the stresses p_0 and p_1 coexist. Accepting this equation as a general condition for the whole section the integrals in (6) do not each of them vanish, but when the expressions under the integral signs are proportional in order of sequence to $\frac{d f}{d p_0} = E_1$ and $\frac{d f}{d p_1} = -E_1$, we shall have $\delta U = 0$. This will be found to lead again to equation (7).

If there had been more than two different materials, we should have obtained a corresponding number of additional terms in the equations (4) to (7) and all of the same form, since the condition $\delta U = 0$ would require that each of the integrals should vanish. Adopting one of the moduli of elasticity, say E_0, as the standard we may write : $\frac{E_0}{E_1} = \mu_1$, $\frac{E_0}{E} = \mu_2$, &c.

Substitute now the value of p_0 and p_1 from (7) in equation (1) :—

$$\int_0^{y1}\int_{-x2}^{x1} E_0 (a y + b x + c)\, dx\, dy$$

$$+ \int_0^{y1}\int_{-x2}^{x1} E_1 (a y + b x + c)\, dx\, dy = 0 \quad . \quad (8')$$

In this equation, as in the following similar equations, the interpretation of the double integral signs is the same as explained above—each of them stands for a group of integrals.

Let m_{x0} and m_{y0} be the moments of area of the material (0) about the axes O X and O Y respectively, and A_0 the area. The corresponding quantities for the material (1) are denoted similarly by the suffix (1). Then (8′) may be written :

$$a\left(m_{x0} + \frac{m_{x1}}{\mu_1}\right) + b\left(m_{y0} + \frac{m_{y1}}{\mu_1}\right)$$

$$+ c\left(A_0 + \frac{A_1}{\mu_1}\right) = 0 \quad . \quad . \quad (8)$$

The terms inside brackets represent the moments and the area of the whole section expressed in terms of the material with modulus of elasticity E_0.

Substituting the value of p in (2), we get :—

$$M = \int_0^{y1}\int_{-x2}^{x1} E_0\, y\, (a y + b x + c)\, dx\, dy$$

$$+ \int_0^{y1}\int_{-x2}^{x1} E_1\, y\, (a y + b x + c)\, dx\, dy \quad . \quad (9')$$

and using a notation for the moments and products of inertias similar to that for the moments we have :—

$$M = -E_0 \left[a I_{x0} + b I_{xy0} + c m_{x0} + \frac{1}{\mu_1}(a I_{x1} + b I_{xy1} + c m_{x1}) \right] \quad . \quad (9)$$

Finally from (3) we get :—

$$a I_{xy0} + b I_{y0} + c m_{y0} + \frac{1}{\mu_1}(a I_{xy1} + b I_{y1} + c m_{y1}) = 0 \quad . \quad (10)$$

Now move the axes of co-ordinates parallel with themselves so that the origin comes to coincide with the centre of gravity of the section, reckoning the elements of the area to be expressed in terms of the respective materials. We have then :—

$$m_{x0} + \frac{m_{x1}}{\mu_1} = m_{y0} + \frac{m_{y1}}{\mu_1} = 0.$$

Since O X and O Y now coincide with the principal axes the product of inertia must be equal to zero :—

$$I_{xy0} + \frac{I_{xy1}}{\mu_1} = 0.$$

Hence we find from (8) that $c = 0$, from (10) that $b = 0$, and from (9) that

$$M = -a E_0 \left(I_{x0} + \frac{I_{x1}}{\mu_1}\right) = -a E_0 I_0 \quad . \quad (11)$$

where I_0 is the moment of inertia of the whole section about the principal axis O X, when the area is reckoned in terms of the material (0).

Equation (7) may now be written :—

$$\left.\begin{aligned} \frac{p_0}{E_0} &= -a y \\ \frac{p_1}{E_1} &= -a y \end{aligned}\right\} \quad . \quad . \quad . \quad (12)$$

showing that the strains $\frac{p}{E}$ are everyhere proportional to the distance from a horizontal axis. This axis passes through the centre of gravity of the section whether we use E_0 or E_1 as the standard, and, since it is characterised by zero strains, it is the neutral axis. It follows that sections which are plane before bending remain plane after bending.

With E_0 as the standard modulus of elasticity, equation (12) may be given the generalised form :—

$$p = -\frac{E_0}{\mu} a y \quad . \quad . \quad . \quad (13)$$

From equation (12) we find also :—

$$a = -\frac{p_0}{E_0 y} = -\frac{\mu_1 p_1}{E_0 y}$$

which is the strain at any point divided by its distance from the neutral axis. This is known to be the reciprocal of the radius of curvature R, so that a is equal to the curvature.

From (13) in conjunction with (11) we obtain now the extended equation for bending :—

$$\frac{p}{y} = \frac{M}{\mu I} \quad . \quad . \quad . \quad (14)$$

where I is expressed in terms of the standard material and μ is the factor for the modulus of elasticity of the material at the point under consideration.

In order not to lengthen this paper unduly, it was assumed at the outset that the axis of the bending moment was parallel to one of the principal axes of the section. If this is not the case, the bending moment denoted by M_H in (3) will not be zero and will appear in equation (10). Besides moving the origin to the centre of gravity, it will then be necessary to turn the axis O X through a certain angle, whereby it will always be possible to make p proportional to the distance from that axis.

It is not asserted that the state of stress and strain defined by this equation actually exists in any ordinary girder, but it is believed to be shown that in accordance with the Principle of Least Work there will be a tendency for the stresses and strains so to adjust themselves as to approach this condition. This tendency agrees with and confirms the Principle of Saint-Venant. The adjustment must be effected primarily in the region of shear by longitudinal traction between contiguous filaments or members which differ in modulus of elasticity. Hence, it is necessary for the attainment of this ideal condition that the lengthwise connection between members of different elasticity shall be such as to permit the effective transmission of longitudinal forces.

APPENDIX II.

Application to Airships.

In non-rigid airships the strength resides entirely in a gas-bag of rubberised fabric, but in rigid airships the structure is usually of duralumin with diagonals of steel wire, and in semi-rigid airships a metal keel is combined with an envelope of fabric and we have conditions to which the above theory applies.

Consider a semi-rigid airship constructed of a triangular keel-girder of duralumin and an envelope of rubberised fabric which serves as gas-bag and which is intimately connected with the lower longitudinals of the keel (see Fig. 2). The keel extends from end to end and is stiffened by transverse triangular frames, while the panels so formed are braced with diagonal wires. The extent to which the keel and the envelope co-operate in resisting bending moments depends entirely on the relative stiffness of the two component parts of the ship-girder. Since the modulus of elasticity of duralumin may be as much as $40{,}000 \times t$ to $50{,}000 \times t$ times as great as that of the envelope in the direction of the woof, where t is the thickness of the fabric in inches, the stresses created in the envelope by bending will not be considerable even if the keel is relatively very flexible. Generally the keel will carry the greater part of the bending moment. Some designers prefer to design the keel to take the entire bending moment, but in so doing they actually adopt the principle of the rigid airship and give up the advantage peculiar to the semi-rigid—that of a relatively light structure. It is to be noted that co-operation between the keel and the envelope is ensured by the fact that the ends of both structures must have almost identically the same longitudinal displacements, due to the upwards curvature of the keel on these regions.

Let I_K = moment of inertia of the keel about the neutral axis of the entire structure,

I_E = moment of inertia of the envelope about the same neutral axis,

$\mu = \frac{E_K}{E_E}$ = ratio between the moduli of elasticity.

Then the moment of inertia of the entire section in terms of duralumin is :—

$$I_{KK} = I_K + \frac{I_E}{\mu}$$

and in terms of the fabric :—

$$I_{EE} = \mu I_K + I_E = \mu I_{KK}$$

The stress in any of the longitudinals of the keel is therefore given by :—

$$p = \frac{y M}{I_{KK}}$$

and in any part of the envelope by :—

$$p = \frac{y M}{I_{EE}} = \frac{y \cdot M}{\mu I_{KK}}$$

The calculation by this method is extremely simple.

In order to demonstrate what this method implies and determine the share of the bending moment which each of the two materials carries, we may conceive the airship here described to be compounded of two structures separated by an imaginary boundary in the lower longitudinals. This boundary splits each of those longitudinals lengthwise in two parts, of which one acts as a reinforcement of the lower edges of the envelope, while the other forms the lower flange of the keel-girder. Its location is so chosen that the neutral plane of each of the two structures is common to both and therefore identical with that of the complete ship. Thus the necessary condition is fulfilled that the stress in the two parts of the lower longitudinals is the same, and we have now two structures which may be regarded and dealt with as perfectly independent, but which yet fit each other and bend together, each carrying a certain part of the bending moment. On this basis the author made a calculation for a certain airship and found that under the assumption of perfect co-operation between the envelope and the keel, the envelope-girder, as just described, carried more than one-third of the entire bending moment.

APPENDIX III.

Application to a Beam of Reinforced Concrete.

The usual method of calculating the strength of reinforced concrete beams rests on the fundamental proposition, which it is the object of this paper to establish, that, in spite of the difference in the modulus of elasticity of the component members, sections that are plane before bending remain plane after bending, and that hence all elongations and contractions are proportional to the distance from the neutral axis. Experiments and experience have shown this assumption to be sufficiently accurate for practical purposes, but the theory advanced above shows that there must, in the nature of things, be a tendency toward this ideal state. It is believed, moreover, that the direct application of the formulæ given in the paper is simpler than the procedures ordinarily followed, although, of course, the two methods give the same result, provided the assumptions as regards the strength of concrete in tension are the same. In order to show the simplicity of the method here proposed, the developments of the formulæ for a rectangular beam is given.

Fig. 2.

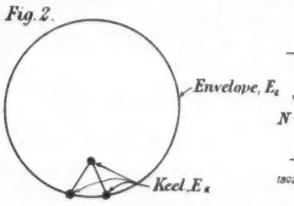
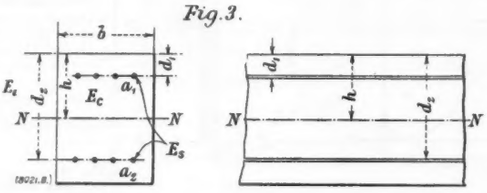


Fig. 3.



A rectangular beam of concrete is reinforced by steel bars both for tension and compression, as indicated in Fig. 3. The beam is supposed to be bent so that the upper bars embedded in the concrete come under compression while the lower are in tension. The concrete is supposed to be inactive in tension, so that only the part above the neutral axis, of area $b\,h$, needs to be included in the calculation. The upper bars are a distance d_1, the lower bars a distance d_2, and the neutral axis a distance h below the top of the beam. The width of the beam is b. The area of the steel reinforcement in the top is a_1 and that in the bottom a_2. Let the moduli of elasticity of the steel bars and of the concrete be E_s and E_c respectively and let

$$\frac{E_s}{E_c} = \mu$$

Then the neutral axis is found from :—

$$h\left[\mu\,(a_1 + a_2) + h\,b\right] = \mu\,(a_1 d_1 + a_2 d_2) + \tfrac{1}{2} b\,h^2$$

from which :—

$$h = -\frac{\mu}{b}(a_1 + a_2) + \sqrt{\frac{\mu^2}{b^2}(a_1 + a_2)^2 + \frac{2\,\mu}{b}(a_1 d_1 + a_2 d_2)}$$

We have here, in accordance with usual practice, included the areas of the section actually occupied by the steel bars in the area of the concrete, simplifying thus the integration. The compressive stress f_c in the concrete at the upper side of the beam is found from :—

$$\frac{f_c}{h} = \frac{M}{\mu I_s}$$

where I_s is the moment of inertia of the whole section expressed in terms of the steel :—

$$I_s = a_1 (h - d_1)^2 + a_2 (d_2 - h)^2 + \frac{b\,h^3}{3\,\mu}$$

$$\therefore f_c = \frac{h\,M}{\mu\,a_1 (h - d_1)^2 + \mu\,a_2 (d_2 - h)^2 + \frac{1}{3} b\,h^3}$$

For the upper and lower steel bars the stresses are respectively :—

$$f_{s1} = \frac{(h - d_1)\,M}{I_s} \text{ and } f_{s2} = \frac{(d_2 - h)\,M}{I_s}$$

These results will be found to check with those obtained by standard methods.

The condition that the formulæ shall apply correctly where the bending moment is created by shearing, as usual in practice, is again that there shall be an adequate lengthwise shearing connection between the various members, or as it is generally expressed, that the "bond" of the concrete to the steel shall be sufficient to prevent slipping.

CATALOGUES.

Engine Indicators.—A catalogue of Dr. Geiger's engine indicator, received from The Lunken Company, Limited, 35, Great Dover-street, London, S.E., describes the instrument in which special care has been taken to reduce the motion of the moving parts and secure a long natural period of vibration, making it thus suitable for indicating high-speed engines and particularly internal-combustion engines. Specimen diagrams are reproduced from oil engines running at speeds up to 450 r.p.m., showing lines very free from vibration effects.

Power-Transmission Accessories.—A new edition of the catalogue issued by Messrs. David Bridge and Co., Limited, Castleton, Manchester, forms a very complete hand book of shafting, bearings, pulleys, tooth gears, couplings, clutches and other power-transmission accessories. In all cases a full range of types and sizes is dealt with and much useful and practical information is given on each. In addition the catalogue contains 50 pp. of technical data, all of which are relevant to the subject and will be found very handy for reference.

Vertical Oil Engines.—A general specification with tables of standard dimensions, and an account of suitable applications, of their vertical oil engines is to hand from Messrs. Marshall, Sons and Co., Limited, Gainsborough. The series of standard engines include 12, ranging from 30 h.p. to 300 h.p. for general purposes, 4 of the smaller single-cylinder engines of the first series with extra heavy flywheels for exceptionally steady running, and 8 marine engines ranging from 60 h.p. to 300 h.p., with two or four cylinders and directly reversible by means of compressed air.

Oil and Petrol Engines.—A new catalogue fully describing their series of oil and petrol engines for land and marine work is to hand from the Parsons Motor Company, Limited, Southampton. The engines range from 14 h.p. to 90 h.p. in the marine type and from 7 h.p. to 90 h.p. in the stationary type. A separate catalogue of special fittings and accessories, which are available with or without the engines, gives particulars of clutches, reverse gears, stern tubes, pumps, fittings, &c. Both catalogues give full and clear particulars of construction and dimensions.

Air Compressors.—A brief descriptive catalogue of their vertical high-speed two-stage air compressors has reached us from Messrs. Robey and Co., Limited, Lincoln. In producing these compressors the designers have endeavoured to arrange for ease of examination and also to render the machines suitable for prolonged operation. The compressed air is cooled at the cylinder and delivery chamber, as well as during the intermediate stage of compression. The catalogue is of a general introductory character which can be supplemented with a more fully particularised catalogue when required.

The Gas Analysing Apparatus.—We have received from Messrs. James Gordon and Co., Limited, of Windsor House, Kingsway, London, W.C.2, a catalogue describing the Duplex Mono Automatic Gas Analyser and recorder. This instrument records alternately the percentages of carbon dioxide and of carbon monoxide in the flue gases. The CO_2 is measured by absorption by caustic potash, in the usual way, and the determination of CO is effected by passing the sample through an electric furnace containing copper oxide. The instrument, therefore, allows the highest percentage of CO_2 compatible with the absence of CO, to be obtained in the furnace.

Expanded Metal.—The use of expanded metal for concrete reinforcement and screen work generally is steadily growing if we may judge from the contents of an octavo catalogue of 175 pages we have received, chiefly devoted to descriptions, and illustrations of the many purposes to which the material is applied and the method of applying it. The standard meshes range up to 6 in. measured across the short axis of the diamond from centre to centre and the material can be made from steel, brass, copper or other metals if required. The material is serviceable in many ways. The manufacturers are the Expanded Metal Company, Limited, Yorkmansion, Petty France, London, S.W.1.

Rotary Air Compressor.—The rotary air blower made by Messrs. Reavell and Co., Limited, Ipswich, is described in a new edition of their catalogue recently to hand. The design is essentially the same as described in previous editions of the catalogue, but the details of construction have been revised to some extent. The machine is of the rolling drum type, in distinction from the types in which the revolving blades rub against the casing. In this type a freely revolving drum carried in ball bearings is interposed between the blades and the casing. The friction effect is limited to that between the casing and the drum and in the ball bearings. The blades move outward under centrifugal force as they revolve and grip the drum internally, causing this part to revolve with them. Eleven standard sizes of the machine are made for air compression and four sizes for exhausting. A medium size (12-in. by 12-in. drum) will deliver 410 cub. ft. of air per minute at 5 lb. per square inch pressure, or 300 cub. ft. at 20 lb. pressure, or intermediate quantities at intermediate pressures. With an increase of speed of 50 per cent. the delivery at any pressure will be rather more than 50 per cent. greater, though with an increased ratio of power. The machine can be driven by belt or by a direct-coupled electric motor.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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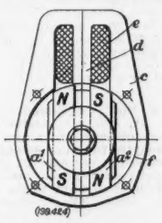
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

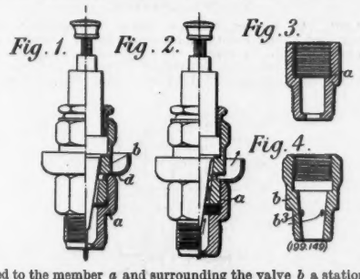
199,424. F. L. Hollister, Richmond, Surrey, and C. A. Vanderveil and Co., Limited, Acton Vale, Acton. Magnetos. (5 *Figs.*) February 20, 1922.—The invention relates to magnetos. Two parallel bar magnets a^1, a^2 are secured to a carrier of non-magnetic material in such a manner that their poles of opposite polarity N, S, shall be adjacent to one another, and the carrier is arranged to rotate within a stationary armature *c* comprising



a small pole *d* on which the ignition coil *e* is mounted and a pole *f* with comparatively large pole surface. The adjacent tips of the bar magnets a^1, a^2 are arranged to overlap the polar surface of the small pole *d*. With this arrangement a reversal of magnetism is effected twice during each revolution, as the one pair of adjacent free ends and the other pair of adjacent free ends pass the small pole *d*, the large pole *f* serving for closing the magnetic circuit. (*Accepted July 4*, 1923.)

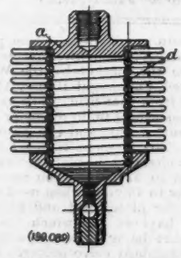
GAS ENGINES, PRODUCERS, HOLDERS, &c.

199,149. M. A. Gray, Brixton, and A. D. Paterson, Ash Vale. Sparking Plugs. (7 *Figs.*) March 18, 1922.—The invention consists of a combined priming and self-cleaning plug comprising two separate and distinct members, viz., a fixed seat member *a* and a relatively rotatable valve member *b*, so arranged that on rotating the valve member *b* in relation to the seat member *a*, it will act as a valve to open and close a number of radial passages b^3 round the valve member itself, so that communication is afforded between the atmosphere and the combustion chamber of the cylinder. There is also



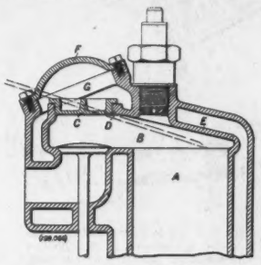
fitted to the member *a* and surrounding the valve *b* a stationary vessel or cup *d* to receive liquid fuel, which, on opening of the passages b^3 by the rotation of the valve as mentioned above, will permit the flow of liquid fuel into the cylinder. The same passages which serve for the flow of priming fuel also serve for the blow back or flow of air or gases under pressure from the cylinder to the atmosphere so that such air or gases will dislodge and remove any solid particles or matter or oil which collect on the electrodes and insulation, thus avoiding the usual cause of short-circuits. (*Accepted June 27*, 1923.)

199,089. A. V. Oliver, Luton. Internal Combustion Engines. (1 *Fig.*) March 10, 1922.—The invention relates to the cooling of internal combustion engines and to thermostatic devices which may be employed to control or operate other apparatus, of the kind comprising an expansible chamber con-



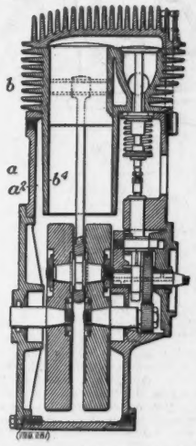
taining volatile liquid and in connection with the apparatus to be controlled. According to the invention, a thermostatic device of the kind described comprises an expansible chamber *a* partly filled with a volatile liquid, such as water, under reduced pressure, and a spring *d* arranged within or without said chamber and acting between opposite ends thereof. For use with a water cooled internal combustion engine in which the engine jacket is connected to a radiator and in which a valve is arranged between the radiator and the engine jacket, the thermostatic device may be employed to operate said valve. (*Sealed.*)

199,066. Sir H. Austin, Bromsgrove. Internal Combustion Engine Cylinders. (1 *Fig.*) February 13, 1922.—The invention has for its object to provide an arrangement whereby the removal of the carbon deposit may be readily effected without removing the cylinders or cylinder heads. A is the cylinder of the usual construction and B the head formed integral therewith. C is one of the valve caps screwed into a socket D of the inner wall E of the water jacket of the head. F is a cover closing an opening G in the outer wall of the



jacket. The opening G is inclined as shown so that, when the covers F and C are removed, an instrument, (as indicated by broken lines), inserted through the socket D to remove carbon deposit is not in any way obstructed by the edge of the opening G, the inner edge of the latter, at its lowest point, passing only slightly above the level of the socket D, whereby the angle at which the instrument may be placed within the cylinder head is limited only by the depth of the socket D. (*Accepted June 27*, 1923.)

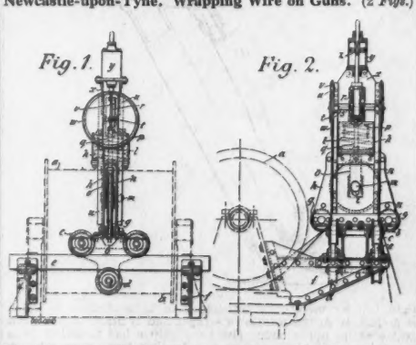
199,281. N. T. Downs, Moseley, Birmingham, and C. H. Dyke, Shirley, Birmingham. Internal-Combustion Engines. (3 *Figs.*) August 3, 1922.—The invention consists in improvements in engines of the type in which the crank-case is extended beyond the part that contains the crankshaft for the purpose of enclosing the lower or inner part of the cylinder and the stems and guides of the inlet and exhaust valves together with their tappets and actuating cams. The improved construction of "all enclosed" engine that constitutes the invention comprises an extended crank-case unit *a* and a cylinder unit *b*,



so constructed that when assembled, the extension a^2 of the crank case *a* terminates approximately at the limit of the outstroke of the piston whereby the working or expansion chamber part of the cylinder, the combustion head and valve pockets are wholly located outside the case *a* and exposed to air cooling, whereas the piston guide portion of the cylinder barrel is contained in the crank-case extension a^2 to enable oil thrown up or and circulating within the case to have access to both the internal and external walls of the part of the cylinder thus enclosed for lubricating, and oil-cooling the same. (*Accepted June 27*, 1923.)

GUNS AND EXPLOSIVES.

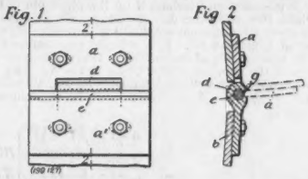
199,082. Sir W. G. Armstrong, Whitworth and Co., Limited, Newcastle-upon-Tyne, and Sir A. G. Hadcock, Newcastle-upon-Tyne. Wrapping Wire on Guns. (2 *Figs.*)



March 8, 1922.—The invention relates to machines for wrapping guns with wire and has for its object to indicate the tension to which the wire is subjected as it is being wrapped on the gun. *a* is a drum upon which the wire is wound, and *b* is the platform of a carriage having wheels *c* engaging the top, and wheels *d* engaging the bottom, of bars *e* carried by brackets *f*. At each side of the platform *b* are guide rollers *g* over which the wire from the drum *a* is led to the gun. Plates *h* are bolted at their lower ends to the platform *b* whilst their top ends support the bottom of a cylinder *k* forming a housing for a spring *l*. The axle *m* of a wheel *n* is carried in slots *i* in a U-shaped plate *o* connected to a plate *p* above the spring *l* by a bolt *q*. Racks *r* are fixed to the plate *p* and mesh with pinion *s* on a spindle *t* supported in bearings in angle irons *u* whose bottom ends are secured to the plates *h*. At the ends of the spindle *t* are pointers *v* which turn relatively to dials *w*. The upper ends of the angle irons *u* are bolted to plates *x* (one of which is omitted in Fig. 2) which carry a dashpot *y* in which is a piston *z* fitted with non-return valves; the piston rod is connected to the piston and to the plate *p*. The wire from the drum *a* passes round one guide pulley *g*, over the wheel *n* and round the other guide pulley *g* to the gun. It will be seen that the wheel *n* is free to move up and down and compresses the spring *l* through the plate *p* according to the amount of tension on the wire, and any movement of the plate *p* is communicated to the pointer *v* through the racks *r* and pinions *s*. (*Accepted June 27*, 1923.)

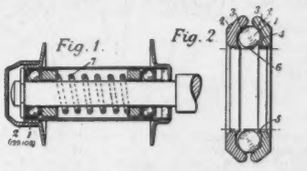
MACHINE AND OTHER TOOLS, SHAFTING, &c.

199,127. B. J. Elston, Copplestone. Fastenings for Driving Belts. (4 *Figs.*) March 15, 1922.—The invention relates to fastenings for driving belts of the kind comprising two plates *a*, *a*1, one of which is slotted so as to provide a hinge-pin *e* along one edge whilst the other plate is formed with a socket or bearing *d* also along one edge within which the pin fits and can turn freely, this bearing being formed with a narrow longitudinal



gap *g* in its upper surface so that when the part of the plate fastening proved with the pin is turned out of line with the other plate fastening, the pin can be withdrawn from the bearing longitudinally. According to the invention, the gap *g* is arranged facing approximately at right angles to the plane of the plate *a*1 so that the plate *a* has only to be turned from its position of use through a right angle to be engaged with or disengaged from the other plate. (*Accepted June 27*, 1923.)

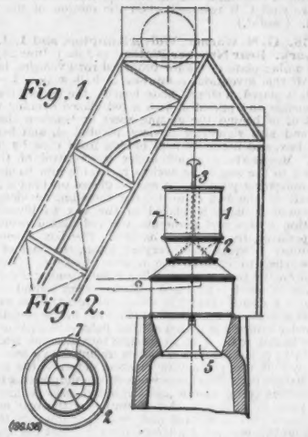
199,108. W. Binns, Bradford Moor, Bradford, and J. D. Mander, Bingley. Ball Bearings. (3 *Figs.*) March 13, 1922.—The invention relates to ball bearings of the type in which the ball has a three-point bearing contact with the races. The invention is characterised by the feature that one of the races is axially movable against spring pressure, which however allows free rotation of the race about the axis of the shaft. The bearing comprises a set of balls 1 and a pair of races 2, which races have inclined bearing surfaces 3, radial surfaces 4 normally out of contact with the balls 1, and inner retaining flanges or lips 5.



In use as a radial bearing, a shaft contacts with the rings of balls at 6 so that each ball has a three point contact, viz., along the line 3 on each of the races 2, and at the point 6 on the shaft, or in a peripheral race on it. Should, however, the shaft be removed the balls will not fall out, with the danger of becoming lost and having the disadvantage of difficulty in re-assembling, but under lateral pressure, such as by means of a spring 7 (Fig. 1), the races 2, 2 will come together so that the balls are held by the lips or flanges 5, and are thus prevented from falling radially inwards. (*Accepted June 27*, 1923.)

MINING, METALLURGY, &c.

199,138. R. C. Harding, Stoke-on-Trent. Charging Blast Furnaces. (2 *Figs.*) March 16, 1922.—The object of this invention is to improve the distribution of the charge par-

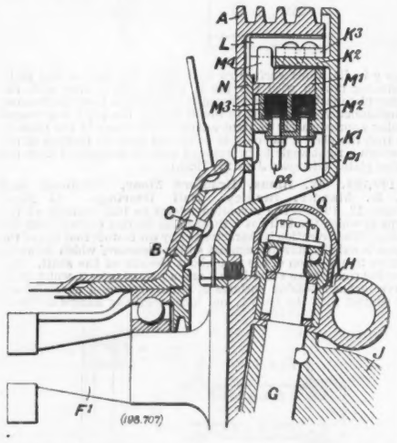


ticularly by distributing it from the bucket into heaps on the main bell 5, the heaps being evenly distributed round the circle. According to the invention, means are provided for depositing

the whole charge from the bucket on the main bell 5 of a blast-furnace in a number of simultaneously formed heaps. In its preferred embodiment, the bucket or the hopper 1 or the vertical rod 3 supporting a bell 2 is provided with vanes or equivalent means 7, adapted to separate the charge and place it on the main bell 5 in heaps while maintaining its distribution even round the circle. Such vanes 7 are preferably vertical and radial and may extend outwards from the centre or inwards from the periphery, but they may be arranged in any convenient way and may be straight or spiral or otherwise curved and may be parallel or taper in section. In operation, the bucket 1 is filled as evenly as possible, the charge being preferably caused to fall upon the centre of the bell 2 and distribute itself between the vanes 7, and when the bell 2 is lowered away from the bucket the charge is divided into an equivalent number of heaps upon the main bell 5 from which it is discharged into the furnace. (*Accepted June* 27, 1923.)

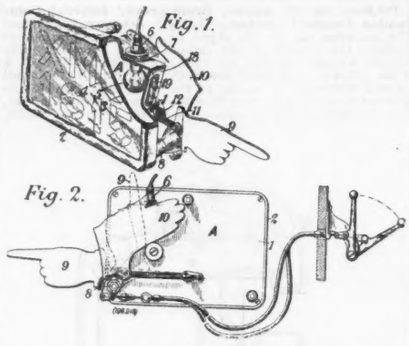
MOTOR ROAD VEHICLES.

198,707. F. W. Lanchester, London, and The Daimler Company, Limited, Coventry. Brake Mechanism. (2 *Figs.*) December 5, 1921.—This invention consists in brake mechanism of the internally expanding ring or coil type, wherein expansion of the braking ring or coil within a brake drum is produced with equal efficacy for both directions of rotation of the drum, by frictional drag between a member abutting one or other of the ends of the ring or coil and an armature member rotationally rigid in relation to the brake drum, the frictional drag being occasioned by electromagnetic attraction between the armature member and the core of a rotationally restrained electromagnet. A is the brake drum mounted on the hub B, adapted to carry the detachable road wheel, which comprises a hub shell C, and which runs as a whole upon ball bearings on the stub axle F^1. This axle is mounted on bearings H on the pivot pin G which is cottered into the axle tree J. The stub axle F^1 also carries the brake cover K^1 which has a cylindrical extension K^2 to which is riveted an abutment K^3. L is a brake ring whose ends are adapted to bear on the abutment K^3. The brake ring L bears directly upon the interior of the brake drum A. An electro-magnet is provided consisting of components M^1, M^2 with windings filling the space M^3. This magnet is of annular form



having its axis in common with the axis of the road wheel. An armature plate N is provided in close juxtaposition to the faces of the components M^1 and M^2 forming the poles of the magnet. An arm M^4 from the magnet projects radially outwards between the ends of the brake ring L. The terminals of the winding occupying the space M^3 are shown at P^1 and P^2 and leads are taken from these through the hole Q in the brake cover K^1 to the controller by which the brake is operated. The action is as follows: When the electromagnet M^1, M^2 is excited by the current supplied to the terminals P^1 and P^2, a frictional grip is established between the poles of the magnet and the armature N and the magnet is dragged round by the motion of the wheel through a small angle until the arm M^4 is arrested by the pressure exerted on the end of the brake ring L. This has the result of expanding the brake ring and bringing it into frictional contact with the brake drum A. The effect is cumulative, the brake acting on the principle of an internal band brake. The brake action is effected whether the wheel is going in a forward or reverse direction, since the motion communicated to the electromagnet M^1, M^2 follows the direction of rotation of the wheel, and the consequent action on the ends of the brake ring L is reversed when the motion of the wheel is reversed. (*Sealed.*)

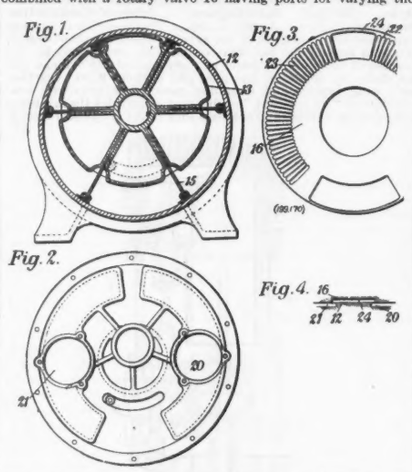
198,918. G. N. Warner, Wolverhampton, and J. J. Pritty, Southwark. Rear Number Plates. (3 *Figs.*) June 24, 1922.—A rear number plate for motor propelled road vehicles, in accordance with this invention, comprises a shallow box A, one side of which is glazed, a stencil plate bearing the registration letters and numerals and provided with a red glazed opening mounted in front of or behind the glazing sheet or between the glazing sheets, and also signalling devices pivoted on and behind the shallow box, and normally held hidden from view by means of springs. Means are provided under the control of the driver connected to the signalling devices to enable him to move them into an indicating position. A second glazed opening is arranged in a wall of the box close to the signalling devices and a single source of light is placed in the box to illuminate the registration letters and numerals, the red glazed opening and, when operative, the signalling devices. The box A comprises a rear member 1, which is of varying depth, the part of greatest depth serving to contain the source of light. Removably mounted on the rear member 1 is a front member 2 constituted of a frame in which is mounted a glazing sheet behind or in front of which is a stencil plate 3 in which the registration letters and numerals are cut. 4 is a circular orifice cut in the stencil plate 3. The circular orifice 4 is glazed so that light rays passing through it are coloured red. 5 is an electric incandescent lamp which is carried by a lamp holder 6 that is mounted in a hole 7 in the upper part of the portion of greatest depth of the member 1 of the shallow box. The lamp when in use illuminates the registration letters and numerals and the red glazed opening 4 in the stencil plate 3. 8 is a bracket mounted on the rear member 1 at the lower portion thereof and extending towards the back. Pivoted on this bracket 8 are two signalling devices 9, 10. The one signalling device 9 comprises a pointing hand and the other signalling device 10 comprises an upraised hand. These signalling devices 9, 10 are normally held in an inoperative position behind the box A by springs 11, 12, respectively, which are attached at their ends to the signalling devices and the rear member 1 of the shallow box A. The signalling devices 9, 10 are operated by Bowden wire or similar mechanism from a position convenient to the driver of the vehicle. The wall 18 subtending the deeper



portion of the shallow box is glazed and the glazed opening 19 is in such position that a beam of light from the lamp 5 will be projected on the signalling device 9 or 10 when in its indicating position. The source of light thus serves to illuminate the stencil plate and the red glazed opening, and, when indicating, the signalling device. (*Sealed.*)

PUMPS.

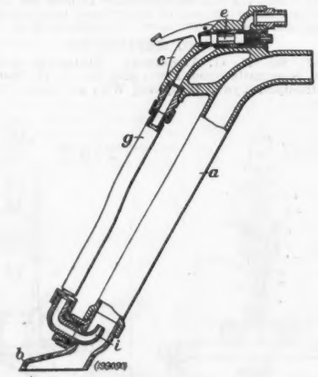
199,170. L. F. R. Feil, London. Rotary Blowers. (11 *Figs.*) March 27, 1922.—The invention relates to rotary blowers of the type comprising a casing 12 formed with inlet and outlet openings and containing an eccentrically mounted rotary drum 13 carrying relatively movable impeller blades or vanes 15 combined with a rotary valve 16 having ports for varying the



inlet and outlet openings. According to the invention, the rotary disc valve 16 is formed with ports 22, 23 extending through it for connecting the inlet 20 and outlet 21 to different points in the working space in the casing 12, for controlling the admission and delivery periods of the compressor, and is further formed with recesses 24 for short circuiting the inlet and outlet, as required. (*Accepted June* 27, 1923.)

SHIPS AND NAUTICAL APPLIANCES.

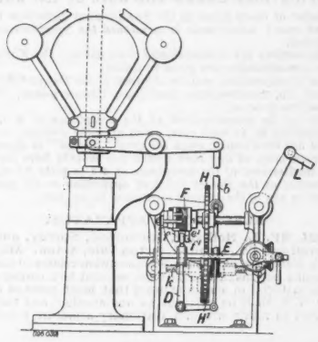
199,090. H. A. Thompson, North Shields. Refuse Ejector Apparatus. (6 *Figs.*) March 10, 1922.—The invention has for its object to provide an improved form or adaptation of the well known type of cleaning apparatus commonly known as a vacuum cleaner. According to the invention, a



rigid tubular member *a* terminates in a mouthpiece *b* which is preferably in the form of a scraper and is fitted with a hand grip *c* at its upper end. The hand grip *c* has mounted upon it a valve *e* and pipe connection *g* leading to an ejector which is located in the tubular member *a* or the mouthpiece thereof. (*Accepted June* 27, 1923.)

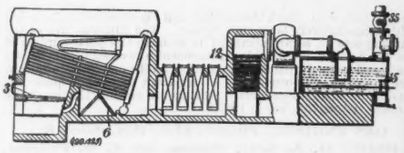
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

196,039. T. Renwick, Hyde. Engine Governors. (2 *Figs.*) January 10, 1922.—In a governor relay mechanism a link *b* is connected to the throttle lever L and adjusted in length by a turnbuckle which is rotated by gearing H^1, H from a ratchet



drum F. The drum is driven in opposite directions by one or other of two pawls *f*, f^1 adapted to be engaged by a finger *e* attached to a constantly rotating shaft E. The finger does not engage either of the pawls until the shaft E is moved lengthways under the influence of the governor by a link *b* and angle lever D. (*Sealed.*)

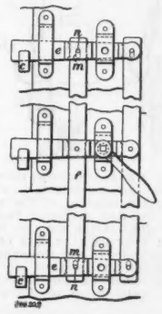
199,425. C. V. A. Eley, Edgbaston. Treating Smoke. (6 *Figs.*) February 21, 1922.—Apparatus for treating smoke and/or gases from furnaces comprises a member 6 consisting of refractory material, adapted to be maintained in an incandescent state to consume completely any unburnt gases or fuel passing from the furnace 3, and a filter 12 or a container for water 15, or both, all arranged within or adjacent to the flue through which the gases pass from the furnace. The refractory element 6 is nearest



to the furnace so that it removes matter from the smoke or gases which would otherwise be detrimental to the filter or the water through which the gases or smoke are subsequently passed. The products of combustion are delivered under the surface of water contained within a tank 15, the tank being provided with a valve controlled outlet 35 through which a mixture of low pressure steam and products of combustion is adapted to pass to suitable engines, turbines or the like. (*Accepted July* 4, 1923.)

MISCELLANEOUS.

199,205. A. Taylor, Newton Heath, Manchester, and Mather and Platt, Limited, Newton Heath, Manchester. Fireproof Doors. (3 *Figs.*) April 29, 1922.—The invention relates to latch and catch devices for fireproof doors, and has particular reference to that type of device composed of a



number of pivoted latches connected together by a vertical rod so that they will act simultaneously. According to the invention, pin and slot connections *n*, *m* are formed between the operating rods *f* and the upper and lower pivoted latches *e* to prevent the latter becoming disengaged from their catches *c* under the heat of a fire. (*Accepted June* 27, 1923.)

A New Thermionic Valve.—Some particulars of a new small-size valve for use in wireless receiving apparatus just placed upon the market by the Western Electric Company, Limited, Connaught House, Aldwych, W.C. 2, have reached us from that firm. The valve, which is of tubular form measuring $\frac{3}{4}$ in. in diameter and $2\frac{1}{2}$ in. long, is of the dull-emitter type and can be operated from a single dry cell. The filament requires 0·25 ampere at from 0·8 to 1·1 volts, and the plate voltage recommended is from 17 volts to 22 volts when used as a detector and from 22 volts to 45 volts when used as an amplifier. Connections to the plate, grid and filament are made by means of a bayonet cap which fits into a special socket, this socket being provided with four pins for fitting into the standard valve holder. It is claimed to be of particularly sound mechanical construction and to have a useful life amounting to twice that of the ordinary tungsten-filament valves and of other dull-emitter valves already on the market.

23.

S, &c.

(2 *Figs.*)

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